Synoptic Water Chemistry Monitoring in the Selway Bitterroot, Cabinet Mountains, and Anaconda Pintler Wilderness Areas

USFS Region 1
Air Resource Management Program

Acknowlegments

A project of this size requires the involvement of a considerable number of people. I would like to thank my fellow employees in the R1 Air Resource Management Program--Ann Acheson and Bob Hammer--for their cooperation, assistance, and considerable support. Louise O'Deen, Steve McGrath, and Jonnie Moore provided the laboratory services. Steve Wegner, Richard Jones, Marilyn Mais, Judith Fraser, and Mary Ann High did an excellent job of coordinating lake sampling collection on their respective Forests. Many samplers were involved and often put in long days in difficult terrain, at times during adverse weather. Bill Putnam was the essential link to the NRDA/CERCLA program. David Nimik (USGS, Helena), Steve Wegner, and Joe Eilers provided thorough reviews of the draft manuscript and offered several useful suggestions which were incorporated into this final report. I would like to particularly thank Joe Eilers for his substantial advice, technical guidance, and outstanding support throughout this Phase 2 program. It is my hope that this information and subsequent Phase 3 monitoring will be used to protect the integrity of the ecosystems of the USFS R1 Wilderness lakes, which are an incredible resource.

M.T.S.

Tammarack lake in the Anaconda Pintler Wilderness Area

Executive Summary

During 1992, 108 lakes in the Selway Bitterroot Wilderness (SBW), Cabinet Mountains Wilderness (CMW), and Anaconda Pintler Wilderness (APW) were monitored for a wide range of chemistry characteristics as part of the USFS R1 Air Resource Management program. Samples were collected by Forest personnel and samples processed by 3 labs for base cations and anions, and in the APW for water metals and lake sediment metals. Analysis of the data indicates good internal consistency and close correlation to the 1985 Western Lake Survey data. Lake chemistry is directly related to parent material. The lakes with least acid neutralizing capacity (ANC) occurred in CMW quartzite watersheds and SBW granitic watersheds. Although no acidified lakes were identified, the lakes with ANC <25ueq/l are considered extremely susceptible to acid deposition. The APW monitoring included lake water metal analysis and sediment cores to assist in the determination if potential exists for metal "injury" from air born contaminants from the old Anaconda smelter. Some APW lakes had "elevated" levels of lead, zinc, cadmium, and copper in lake sediments. These elevated levels are marginal exceedances of biological metal water quality criteria but correspond to identified mineralized zones in the APW. The applicability of the APW lake sediment data must be qualified since several sampling design limitations constrain the data conclusiveness. Phase 3 lakes are tentatively identified for future monitoring including three in each of the CMW and APW and four in the SBW. Phase 3 protcols are also identified. Lake and watershed information needs are discussed which would be used to calibrate each lake to the MAGIC model for future prediction of acid deposition effects on lake chemistry.

Outline

1992 Synoptic Water Chemistry Monitoring in the Selway Bitterroot, Cabinet Mountains, and Anaconda Pintler Wilderness Areas, USFS Region 1

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1) INTRODUCTION

During June-October of 1992, 108 lakes were sampled in USFS Region 1 Class 1 Wilderness Areas as part of the ongoing Air Resource Management Program (USFS, 1990). Fourty four lakes were monitored in the Selway Bitterroot Wilderness (SBW) in the Bitterroot, Clearwater, and Nez Perce NF's, 19 in the Cabinet Mountain Wilderness (CMW) in the Kootenai NF, 39 in the Anaconda Pintler Wilderness (APW) in the Deerlodge, Beaverhead, and Bitteroot NF's, and 6 lakes in the Deerlodge NF adjacent to the APW.

The 1992 sampling accomplished the majority of the Phase 2 monitoring described in Acheson et.al. (1992) and was designed to provide comprehensive chemical information on a variety of lakes in each Wilderness area. The Phase 2 sampling is much more detailed than the pH, conductivity, and alkalinity monitoring completed for the 93 Phase 1 lakes in 1991 in the SBW and Cabinet Mountain WA's (Story, 1991). The primary focus of the synoptic monitoring is to provide an overall perspective of the types and variety of chemical processes in Wilderness lakes in sufficient detail to facilitate tentative selection of Phase 3 lakes (long term benchmark monitoring of a few lakes) pending the completion of the Air Quality Related Value monitoring and inventory plans.

Specific Objectives of the 1992 monitoring and subsequent analysis include:

1) Identify chemical charactistics for a wide range of anions, cations, and other selected parameters for approximately 50% of the previously sampled (1991) Phase I lakes in the SBW and CMW. Lakes sampled included a geographical distribution over each of 4 quadrants in each Wilderness area with a focus on low ANC (acid neutralizing capability) lakes.

2) Tentatively identify 4 lakes in the SBW, 3 in the CMW, and 3 in the APW which would be suitable for long term benchmark (Phase 3) monitoring of lake chemistry for acid deposition and other atmospheric deposition related changes in lake chemistry and associated biota.

3) Tentatively identify Phase 3 protocols (chemical parameters, sampling intensity, duration, and additional factors) for consideration in the preparation of the CMW (1993), SBW (1994) and APW (1995) AQRV plans.

4) In addition to the Phase 2 parameters, measure metal concentrations in lake water in the 46 APW lakes, and in sediment cores from 9 lakes in a transect across the APW.

5) Conduct an investigation to determine whether potential for "injury" exists in the form of lake sediment and/or water column elevated metal concentrations in the APW lakes which may be related to the Anaconda smelter which operated from 1902 to 1980. Provide a recommendation if a "pre-assessment screen" is warrented. This investigation is part of the National Resource Damage Assessment (NRDA)/Federal Facilities Compliance Program (FFCP)/Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

2) METHODS

Lake Selection Criteria: Lakes in the SBW and CMW were selected for 1992 monitoring using the following criteria:

* rank 1991 Phase 1 lakes by gran alkalinity

* plot spacial distribution of lakes

* evaluate geographical distribution

* choose headwater systems over downstream lakes in a lake chain

* easy access (everything else being equal)

* Give priority to low ANC lakes but sample a few moderately buffered and well buffered systems

* Include a geographical distribution with includes at least some lakes in each of 4 quadrants in the SBW, CMW. and APW.

* Exclude lakes to the extent possible where anthropogenic influence occurs (such as the Bitteroot NF lakes which have dams)

The APW lakes were selected using most of the above criteria. Since Phase 1 data was not available, the APW lakes were primarily selected to establish a uniform geographical distribution. The 9 lakes sampled for sediment cores were distributed along the APW at various distances from the Anaconda smelter.

Samplers

All of the 1992 sampling was done by personnel on each of the respective Forest's under the direction of sampling coordinators.

Cabinet Mountains Wilderness--Kootenai NF sampling coordinator--Steve Wegner
Samplers--Charlie Clough, Charlie Peterson, Glen Gibson, Jon Jeresek, Jim Wardensky, Marty Moeller, Mark Story, Steve Wegner

Selway Bitterroot Wilderness--Clearwater NF sampling coordinator--Richard Jones
Samplers--Lawrence Clark, Gale Howard, Mike Howard, Jim Griffith, Jim Bellatty, Debbie Clark, Scott Wallace, Jason Merrihew, Jed Merrihew, Josh Jones, and Richard Jones

Bitterroot NF sampling coordinators--Bob Hammer and Marilyn Mais
Samplers--Bill Goslin, Marty Almquist, Tom Gionet, Sally Blevins, Cass Cairns, Bob Oset

Nez Perce sampling coordinator--Mary Ann High
Samplers--Jim Smolczynski, Ari Posner, Erin Law, Steve Brashear, Mary Ann High

Anaconda Wilderness sampling coordinators--Judith Fraser Wendy LaBahn
Samplers--Kim Corette, Sarah Fleisher

Field Procedures

Lake water samples were collected at a sample depth of about 0.5 meters in the predominately downwind part of the lake, usually by wading. In the APW lakes which had sediment cores taken, the water samples were collected from an inflatable raft. Sample bottles included a 250 ml amber sample bottle, 500 to 1000 ml field bottle for onsite chemistry, and in the AP lakes an additional 250 ml clear bottle which was immediately treated with nitric acid. At about each 10 lakes duplicates and field blanks were taken. Samples were kept cool in field coolers using frozen gell packs or chemically activated cold compresses and shipped to the labs soon after returning to the field stations.

Field pH was measured using colorpHfast (EM Science) indicator strips (4-7 range and 6.5 to 10 range). Field alkalinity was titrated using a 100ml sample, 0.2 N H_2SO_4, and brom cresol green-methyl red indicator to the first permanent pink (about pH 4.5).

Photographs were taken of each lake and lake watershed. Field forms were completed with sampling condition, geographic information, geological type, local geological observation, soil vegetation conditions, watershed and snowpack conditions, and other factors which might affect affect water chemistry. In November field forms were typed and lab chemistry data, maps, and photographs were appended. The field forms are available on each Forest.

Periphyton samples were collected in the Montana lakes by scraping off algae from the upper surface of nearshore rocks and logs, placing in small vials, stabilizing with Lugol's solution, and shipping to Dr. Loren Bahls of the Montana Water Quality Bureau. Loren is coordinating with the EPA in comparing periphyton samples with water chemistry in a number of Montana lake systems. The periphyton information is not currently available so will not be discussed in this report.

In 9 lakes in the APW, sediment core bulk samples were taken from an inflatable raft in 5' to 10' of water with a 1&5/16" O.D. drill rod, split tube sampler, L.A.D. retainer and trap valve. Samples varied from 1" to 6" in depth with the average about 3". Sample texture varied considerably among the lakes but was not measured. Samples were stored in ziplock bags and transported to the laboratory, usually within 1-3 days after collection.

Laboratory Procedures

Three laboratories were used for various aspects of the chemistry analysis. The USFS Rocky Mountain Station Biogeochemistry (Fort Collins) analyzed most of the water chemistry parameters. The Montana Bureau of Mines and Geology laboratory in Butte ran total metals for the APW lakes, and semi-quantitative scan of lake sediments. The University of Montana Geology laboratory in Missoula conducted additional metal analysis on extracts from the bottom sediments using intensive digestion and extraction techniques. Laboratory methods included:

Rocky Mountain Station Biogeochemistry laboratory: pH & alkalinty--Acid Rain Analysis System (ARAS) gran technique; specific conductance--YSI meter; chloride, sulfate, nitrate, ammonia, phosphate, calcium, potassium, sodium, magnesium --liquid ion chromatography; floride--ion specific electrode;

aluminum and silica--Lachat flow injection system. Selected magnesium and calcium chromatography values were checked with atomic absorption (Thermo Jarrell Ash 22E). All analyses used QA/QC guidelines and EPA reference standards established in the Handbook of Methods for Acid Deposition Studies (EPA 600/4-87/026 and Standard Methods (APHA, 1989). The data was reviewed for conformance with quality assurance standards prior to use in this study. Some of the higher magnesium values were readjusted using natural log rather than linear regressions to compute reported concentrations.

Montana Bureau of Mines and Geology laboratory--total recoverable concentrations of beryllium, manganese, iron, copper, zinc, arsenic, cadmium, and lead were determined on unfiltered water samples using EPA method 200.8 consisting of nitric acid/hydrogen peroxide digestion and measurements taken with a Perkin Elmer ICP-MS. The QA/QC procedures included internal standards (blanks, standards, and samples), internal and continuing calibration verification, calibration blanks, laboratory reagent blanks, lab fortified blanks, USGS reference control samples, and pre-digestion spike additions. Data were reported in ug/L. The standard samples were within the 20% relative percent difference except spike recoveries were outside the limits for iron, zink, and beryllium. Zinc showed extreme varability which may indicate zinc contamination from reagent acids, membrane filters, or glassware.

The APW sediment samples were homogenized by thoroughly shaking the ziplock bags, extracting 10 g of sub-sample and digesting 1 gram with nitric acid and hydrogen peroxide (EPA Method 6020), and scanning for 74 elements using the ICP-MS. Two seperate portions were taken from each sample for moisture determination so the final results could be reported in mg/kg (ppm) on a dry weight basis. A certified laboratory contol soil sample (LCS) was also analyzed. For most of the parameters the measured concentrations were within to the advisory range of the LCS.

University of Montana Geology lab--dry extracts from the homogenized APW sediment samples were dried, crushed and sieved through a 0.3 mm nylon screen mesh, 0.5 g extracts were then "pre-digested" with hydrogen peroxide then placed in a sonnicator for 2 hours for thorough organic breakdown. Additional extraction was then achieved by digesting with 5 ml of aqua regia (hydrocloric and nitric acid) for 5 minutes in a microwave, centrifuging, and analyzing on an ICAP for 28 elements. Past QC results for the lab, using USGS standard samples, measured recovery for most elements close to 100% but varying from 72% to 112%.

3. RESULTS AND DISCUSSION

Quality Analysis

Appendix 1 contains synoptic water chemistry data for each of the 108 lakes in mg/L. Appendix 2 provides the synoptic water chemistry data in ueq/L. May lake in the SBW was excluded from the data set as an outlier because the sample was evidently contaminated during field collection. Measured nitrate in May lake was 834 ueq/L (in the WLS May lake had a nitrate value of 0.2 ueq/L) which was 96 times as high as the 2nd highest nitrate value of 13.97 ueq/L for Maple lake in the SBW. Average values for each of the Wilderness areas are shown in Table 1 for mg/L and ueq/L. Table 2 displays the QA/QC results for duplicate lakes and the deionized water field blanks. Duplicate sampling results indicated excellent lab precision. Most of the measured parameters were within 5% of each other. The widest range in field duplicate values occurred in NH4 and Cl. The 11 field blank samples of deionized water indicated that contamination from field or laboratory was not a problem.

A check of the internal consistency of the data was done by the lab by calculation of the % ion difference between anions and cations (Appendix 2). A slight bias toward higher cations than anions was measured with an average difference of 6.85%. This can be considered within an acceptable range since several minor chemical constituents were not measured (primarily organics).

Table 1. Average Values, and Standard Deviation for 1992 Synoptic Lake Surveys
Anaconda Pintler, Cabinet Mountains, and Selway Bitterroot Wilderness Areas

MG/L

attribute	pH	Conduct.	Ca	Mg	Na	K	NH4	F	Cl	NO3	SO4	SiO2	P
average APW	7.39	44.59	7.49	0.84	0.79	0.72	0.04	0.04	0.28	0.05	1.97	3.67	0.02
stnd dev APW	0.61	34.02	7.29	0.81	0.49	0.47	0.04	0.29	0.29	0.15	2.18	2.20	0.11
average CMW	6.88	19.06	2.49	0.64	0.47	0.28	0.03	0.00	0.31	0.01	0.68	2.21	0.00
stnd dev CMW	0.52	18.54	2.51	0.66	0.56	0.28	0.02	0.00	0.69	0.05	0.54	1.12	0.00
average SBW	6.55	9.46	0.79	0.10	0.54	0.23	0.07	0.00	0.27	0.03	0.42	2.77	0.00
stnd dev SBW	0.19	13.10	0.54	0.09	0.22	0.15	0.24	0.00	0.36	0.13	0.40	0.92	0.02
average all lakes	6.96	26	3.90	0.50	0.63	0.44	0.05	0.02	0.27	0.04	1.12	3.05	0.01

UEQ/L

attribute	CA	MG	NA	K	NH4	FL	CL	NO3	SO4	ANION	CATIO	ALK	ANC
average APW	373.9	69.3	34.6	18.5	2.2	2.3	7.9	0.8	41.0	481.5	498.5	446.4	429.4
stnd dev APW	363.7	66.4	21.2	12.0	2.1	15.3	8.1	2.3	45.4	421.1	421.4	420.5	421.5
average CMW	124.2	52.3	20.6	7.1	1.6	0.0	8.8	0.2	14.1	191.9	206.0	181.1	168.8
stnd dev CMW	125.2	54.6	24.2	7.2	1.3	0.0	19.5	0.7	11.3	195.2	185.4	174.3	186.1
average SBW	39.6	8.3	23.4	5.8	3.9	0.0	7.6	0.6	8.8	89.6	81.3	39.3	51.8
stnd dev SBW	27.1	7.2	9.7	3.8	13.2	0.0	10.2	2.2	8.4	137.6	40.0	138.4	40.7
average all lakes	194.7	41.2	27.4	11.4	2.7	1.0	7.8	0.6	23.3	270.7	277.6	235.1	230.2

Table 2. Quality Assurance results from Duplicate Lake Samples and Field Blanks (deionized water)

			uS/cm	------	-	-	-	----MG/L	-	-	-	---------	UEQ/L	MG/L	MG/L	UG/L
	AREA	pH	Conduct.	Ca	Mg	Na	K	NH4	F	Cl	NO3	SO4	ANC	SiO2	P	Al
UPPER LIBBY LAK	CMW	*****	1.954	0.091	0.012	0.142	0.059	0.028	0.000	0.076	0.000	0.219	6.100	0.948	0.000	6.390
UPPER LIBBY LAK	CMW	*****	1.840	0.076	0.012	0.127	0.036	0.007	0.000	0.050	0.000	0.204	5.200	1.074	0.000	9.145
SIAH LAKE	SBW	*****	26.010	3.114	0.601	0.552	0.303	0.013	0.000	0.079	0.000	0.549	237.900	4.593	0.000	18.475
SIAH LAKE FD	SBW	*****	26.316	3.137	0.592	0.546	0.303	0.023	0.000	0.063	0.000	0.591	240.400	4.387	0.000	21.489
BUCK LAKE	SBW	*****	9.628	1.098	0.199	1.064	0.165	0.000	0.000	0.112	0.000	0.129	83.500	2.784	0.000	2.679
BUCK LAKE FD	SBW	*****	9.808	1.144	0.190	1.040	0.165	0.000	0.000	0.081	0.000	0.074	85.500	2.777	0.000	2.174
BLANK	APW	*****	1.064	0.052	1.502	0.074	0.000	0.076	0.000	0.000	0.017	0.000	-1.800	0.939	0.000	2.677
BLANK	APW	*****	1.127	0.148	0.000	0.000	0.000	0.010	0.000	0.000	0.144	0.000	-2.500	0.790	0.000	6.879
SIAH LAKE FB	SBW	*****	1.105	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.864	0.000	0.204
UPPER GEIGER FB	CMW	*****	1.123	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.000	0.000	5.648
GRANITE LAKE FB	CMW	*****	1.204	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000
NELSON LAKE FB	SBW	*****	1.289	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.800	0.522	0.000	3.725
FIELD BLANK	SBW	*****	0.948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.100	0.499	0.000	3.230
BLANK	APW	*****	1.330	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.100	0.155	0.000	0.433
CONTROL BLANK	SBW	*****	1.158	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.500	0.791	0.000	0.000
CONTROL BLANK	APW	*****	0.973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-2.200	0.053	0.000	0.000
BUCK LAKE FB	SBW	*****	1.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-4.900	0.965	0.000	0.000
	AVERA	*****	1.130	0.026	0.138	0.007	0.000	0.008	0.000	0.000	0.015	0.000	0.209	0.507	0.000	2.072

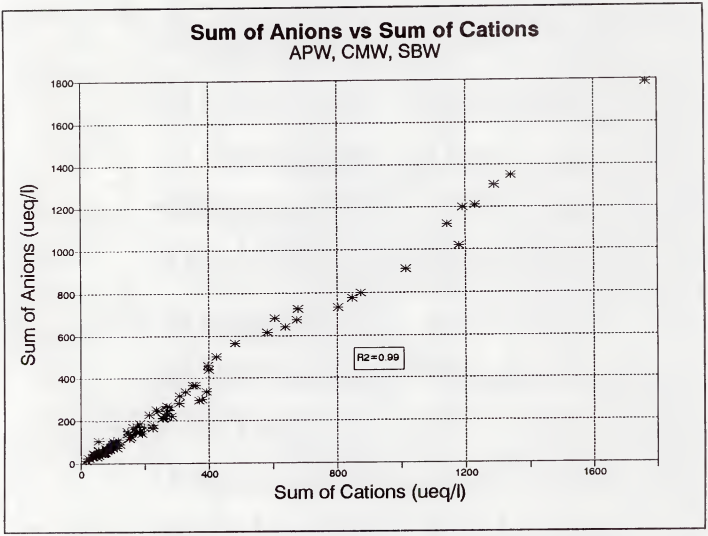


Figure 1. Sums of anions were regressed against the sums of cations for each lake with a correlation coefficient of 0.99. The standard error of Y estimate was 34.1 ueq/L. The close relationship between anions and cations supports overall confidence of the internal consistency of the lab data.

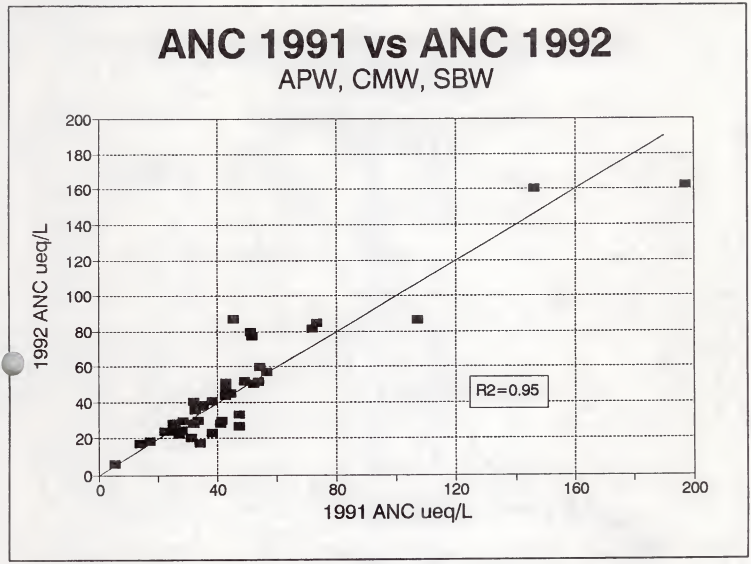


Figure 2. Comparison of ANC (acid neutralizing capacity which equals the sum of base cations minus the acid anions in ueq/l) for lakes which were sampled both in 1991 and 1992. The overall correlation of R2=0.95 was good. The standard error of Y estimate was 23.7 ueq/L. The difference for a given lake may be due to seasonal variation in that the samples were not necessarily collected during the same part of the summer/fall in 1991 and 1992. Yearly variation is also probably a factor since 1991 and 1992 had very different distribution patterns of snowfall and summer rain.

<u>Lake Chemical Characteristics</u>

Several lake chemical characteristics (gran ANC vs conductivity, calcium vs conductivity, and silica vs base cations) will be shown in figures to illustrate some of the chemistry findings and relationships.

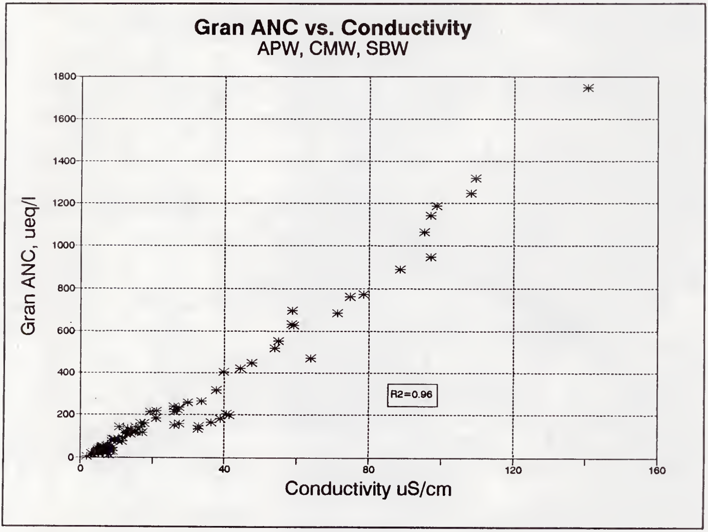


Figure 3. Gran titration measured ANC compared closely with conductivity (R2=0.96). Standard error of Y estimate was 68.3 ueq/L. This result is similar to the 1991 Phase 1 results (which also had an R2 of 0.90 between gran ANC and conductivity) and supports Eilers et.al. (1991a) contention that conductivity is an inexpensive and reliable parameter to index buffering capacity in dilute lake systems.

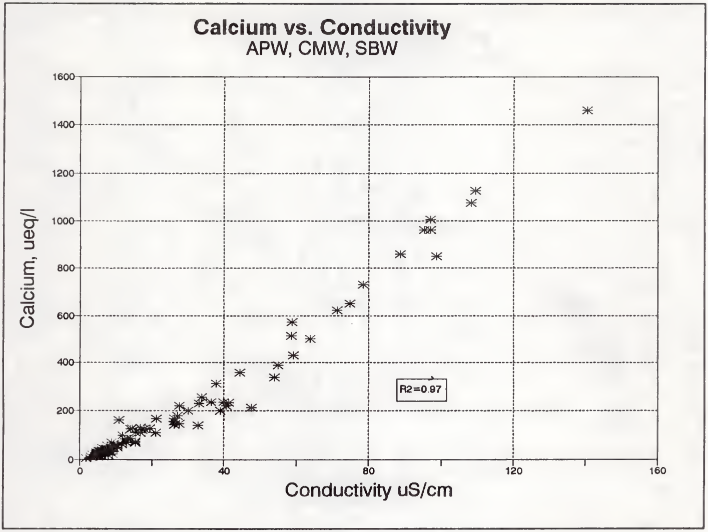


Figure 4. Calcium also correlates well with conductivity (R2=0.97). Standard error of Y estimate was 1.08 ueq/L. This finding is comparable to figure 3 and indicates that the predominant cation from weathering is calcium. This result also compares closely with Turks (1991) evaluation of WLS data for the Bitterroot range where he reported an R2=0.92 correlation between calcium and ANC. Turk (1991) concluded that the high correlation between calcium and ANC in the Idaho Batholith watersheds indicates preferential weathering of calcium. Clayton (1988), in Idaho Batholith granitic watersheds similar to the SBW, found preferrential weathering of anorthite rich feldspar within zoned plagioclase. Cations were being released by silicate mineral weathering. Turk (1991) concluded that rapid physical removal of weathered material and exposure of fresh mineral surface material maintains the high percentage of calcium in the Batholith water chemistry.

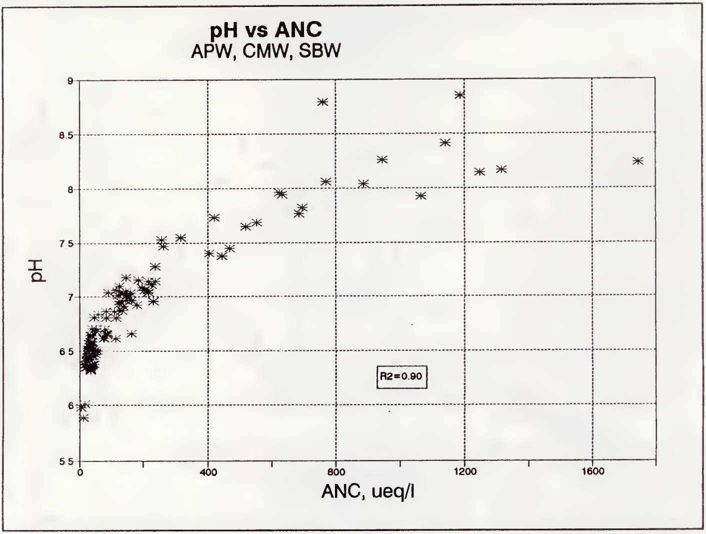


Figure 5. Lab pH compared reasonably closely to ANC (R2=0.90). The regression was run using log pH vs log ANC with a standard error of Y estimate of 0.01 pH units. Since pH is "regulated" by the amount of dissolved bicarbonate (major component of ANC) and the partial pressure of CO2, a close relationship is expected. The lower pH samples (below 6.0) are field blanks of deionized water. The greatest "departure" occured for Little Johnson (pH 8.8) and Kelly (pH 8.7) lakes in the APW. These shallow lakes were sampled during mid-day when evidently, macrophyte photosynthesis drew heavily on the dissolved CO2 (carbonic acid) resulting in relatively low amount of H+ (hence the high pH). The pH would be expected to drop by a unit or more at night. The process of 1-2 unit diurnal pH fluxuation is common in shallow lakes and ponds (Hutchinson, 1975).

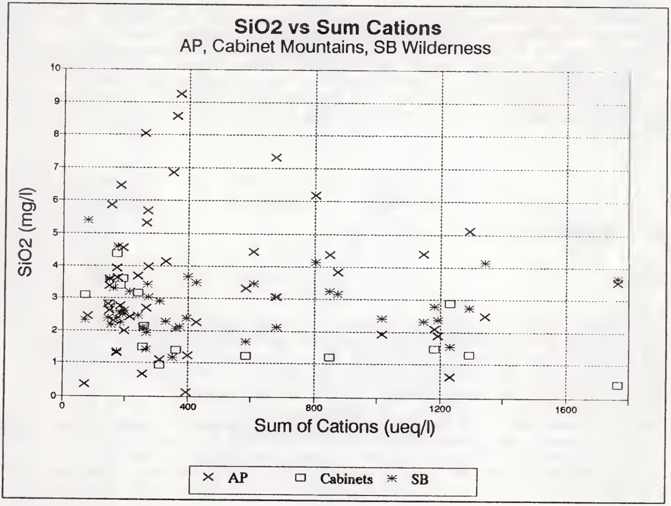


Figure 6. Silica did not correlate well with the base cations. Part of the reason is that silica occurs as an uncharged species. Silica is not particularly soluble, unlike the cations Ca, Mg, Na, and K which are charged and more soluble. Silica is released in weathering reactions and occurs in much lower concentrations than the base cations. This indicates that most of the base cations in the lakes (and associated alkalinity) are not being generated from of silica material but rather by weathering of calcite and other more readily weatherable minerals. The overall correlation coefficient between base cations and SiO_2 was only $R2=0.02$. However when individual Wilderness area data was examined the APW had an $R2=0.00$, CMW of $R2=0.04$, and the SBW of $R2=0.18$. The higher, although still poor, correlation of SiO_2 with base cations in the Selway Bitterroot Wilderness lakes is probably due to the relatively high silica content in the bedrock of the Bitterroot range which has Lower Cretaceous granite, granitic gneiss, and quartz monzonite associated with the Idaho Batholith. Per amount of ANC, the SBW would be expected to produce less base cation generation (and associated alkalinity buffering) per acid rain increment than the APW Lakes and non-Ravalli quartzite lakes in the CMW which have higher levels of carbonate minerals.

Comparison with 1985 Western Lake Survey Data

The 1992 Region 1 lake data is similar to the 1987 Western Lake Survey data (Landers, 1987). Appendix 3 lists the 1992 R1 and the WLS data for all lakes which were sampled in both surveys. Data agreement is generally very good, particularly for ANC, base cations, and sulfate. The 1992 data evidently under reports floride and over reports NH4. Eiler's (1987b) summarization of the Northern Rockies WLS data is shown below. The 1992 R1 monitoring selected a higher percentage of low ANC lakes with base cations less than 50 ueq/L. The percentage of lakes with sulfate greater than 50 ueq/L was close for both data sets.

	ANC <50 ueq/L	SO4 >50 ueq/L	Base Cations <50 ueq/L
WLS, Northern Rockies	12.7%	10.7%	5.1%
1992 R1	38%	10.2%	10.1%

The higher percentage of low ANC and base cation lakes in the 1992 data is probably due to the 1992 selection criteria focus on low ANC systems, based on ANC data from the 1991 Phase 1 sampling of 93 lakes in the SBW and the ANC information from the Nez Perce NF High Lakes Fisheries Project (Bahls, 1990). The WLS used a random stratification lake selection process.

Identical lakes sampled in both the WLS and 1992 R1 compared closely for the Bitterroot range. For example Eilers (1987) calculated average values for several parameters in the 37 Bitterroot range lakes sampled in 1985 which can be compared to the averages for the same parameters in the 44 lakes sampled in the SBW in 1992.

	pH	ANC ueq/L	Base Cations ueq/L	SO4 ueq/L
WLS, Bitteroot Range	6.79	70	98	9
R1 1992, SBW	6.55	52	90	9

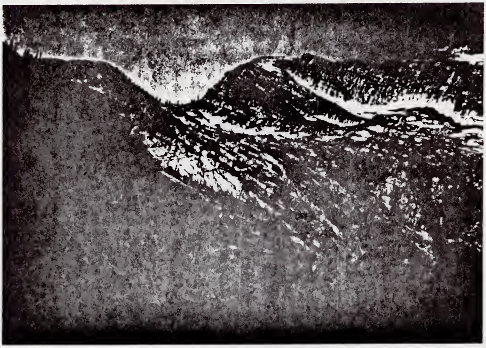
The lower 1992 values are also probably due to the R1 92 selection criteria focus on lower ANC lake systems in the Selway Bitteroot Wilderness.

Geology/Geochemistry and Water Chemistry

Selway Bitterroot Wilderness--Toth's (1983) geologic map of the SBW displays the predominance of intrusive rock of Cretaceous to Tertiary age in the parent material. The primary bedrock type is Lower Cretaceous granite, granitic gneiss, and gneiss or quartz monzonite. Minor amounts of sedimentary rock impregnated with granitic material are also present. The two predominant parent material complexes in the SBW include 1) TKg intrusive granodiorite and quartz monzodiorite and 2) Ymi metasedimentary shist and gneiss intruded with granite. Dominant minerals include quartz and plagioclase which consists of about 60-70% SiO2 and about 3-5% calcium oxide and sodium oxide (Travis, 1955). Weathering from plagioclase results in a relatively high average percentage of sodium in the SBW lakes (23.4 ueq/L) and silica (2.77 mg/1L as shown in Table 1. The predominant granitic matrix in the SBW, however, weathers slowly, with low amount of ANC. Average ANC for the SBW was only 51.8 ueq/L (compared to 65.4 for the 1991 Phase 1 sampling). The WLS (Eilers, 1987a) lakes sampled in the Bitterroot mountains had an average ANC of 70.4 ueq/L which was the 3rd lowest median ANC value of any mountain range in the Western US. A list of the lakes by ANC (Appendix 4) shows that the SBW contains 44 of the 50 lakes sampled in 1992 with ANC less than 50 ueq/L. The highest concentration of low ANC lakes in the SBW occurs in the northeast part of the Wilderness along the Bitterroot crest in the Bitterroot NF. Several of these low ANC lakes are cirque lakes at or near timberline such as Kootenai lakes, Holloway lake, Heinrich lake, and Pear lake. Other low ANC lakes also occur near timberline in the west and south part of the Wilderness including Shasta Lake in the Nez Perce NF and Kettle lake in the Clearwater NF. The ANC in lower elevation SBW lakes is evidently enriched by vegetation in the lower elevation montane lakes (even in the Ymi and Tkg parent material). Examples include White Sand Lake (86.9 ueq/L) and Middle Lake (87.3 ueq/L).

Cabinet Mountains Wilderness--The CMW has a larger range of geology and lake water chemistry variability than the SBW even though the CBW is much smaller. The geologic map of the Cabinet Wilderness shows that the 1992 lakes sampled occur on 3 Precambrian Belt series formations: Ravalli, Prichard, and Wallace, and also in intrusive granodiorite (Johns, 1970). The Ravalli formation is exposed only in the sourthern part of the Cabinets. This formation is predominantly quartzite in the CMW with some argillite. Travis (1955) indicates that quartzite typically has over 70% SiO2 with more sodium than calcium. The quartzite weathers quite slowly with resulting lake chemistry of very low ANC (lower that most "granitic" watersheds which have more feldspars). Upper and lower Libby lakes, Bramlett Lake, and Engle are in Ravalli quartzite watersheds and have very low ANC that range from 6 to 35 ueq/L. Upper and Lower Libby lakes have the 1st and 3rd lowest ANC of any lakes measured in USFS R1, including any in the SBW. The Prichard Formation is also predominantly argillite and quarzite. Lakes in this formation also have low ANC around 50 ueq/L. In considerable contrast is the heterogenious Wallace Formation which has predominantly calcareous or dolomitic argillite and shale with some sandstone, dolomite, and limestone. These carbonate bearing strata weather much faster than the Ravalli or Prichard formations. Calcareous rock types have a high percentage of Ca, Mg, and low SiO2 content (Brownlow, 1979). The ANC in the lake water is much higher than the quartzite or argillite dominated systems. For example, Minor Lake, Leigh Lake, and Upper Sky have ANC's ranging from 400 to 600 ueq/L, and much higher concentrations of calcium and magnesium than sodium.

Upper Libby Lake in the CMW. This small lake and watershed are perched on the Cabinet Mountain crest in Ravalli quartzite with the lowest ANC (6.1 ueq/L) of any lake measured in USFS R1.



Leigh lake in the CMW. This highly scenic lake is one of the most accessible and heavily used in the CMW. Parent material is the Belt series Wallace formation which has some calcareous material. The ANC was measured at 73.4 ueq/L in 1991 and 85.2 ueq/L in 1992.

Anaconda Pintler Wilderness--The APW geology is extremely complex. Zimbelman's (1986) geology maps show that the Anaconda range is composed mostly of two rock types: sedimentary Middle Proterozoic (Precambrian) and Paleozoic age, and igneous rocks, mostly granodiorite to granitic, of Cretaceous to Tertiary age. The Precambrian Belt series formations include carbonate rocks of the Helena and Wallace formations. Cambrian sedimentary rocks are primarily quartz sandstone, shale, limestone, siltstone, and dolomite. The Cretaceous and Tertiary igneous rocks are exposed throughout the APW in a complex series of stocks, plutons, and dikes. In general the southwest part of the range is dominated by granodiorite Cretaceous igneous rocks while the central section has considerable belt series carbonate formations (Helena and Wallace). The northeast part of the APW includes a complex pattern of Belt series and igneous outcrops. Several mineralized zones have been identified in the APW (Elliot et. al., 1985) including 7 which have moderate and moderate/high potential for resources of silver, copper, molybdenum, lead, tungsten, tin, gold, and zinc in various deposit types. Water chemistry in the APW lakes is correspondingly complex. Average calcium is higher than for the CMW or SBW (Table 1) as well as ANC. The most notable chemical contrast between the APW and CMW and SBW is the much higher sulfate levels. This finding is consistent with Eilers (1987) report for the 12 WLS lakes sampled in the Anaconda range which had a sulfate median of 32 ueq/l, the higest in the northern Rockies. This sulfate is probably related to the intrusive mineralization in the Anaconda range (Elliot et.al, 1985) which often contains sulfide bearing rocks.

Lost Lake #1 in the APW. This lake is located in the Mount Shields formation (Yms argillite and quartzite). This lake is among the more sensitive in the APW (ANC was measured at 125 ueq/L). Lost Lake #1 was tentatively recommended for Phase 3 monitoring because it is one of the few alpine lakes in the APW and has a non-complex watershed for watershed/lake chemistry modeling.

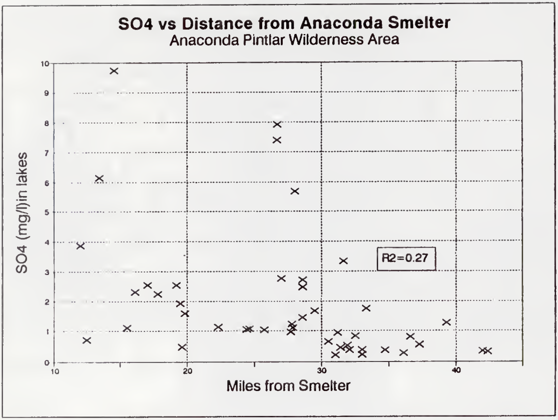


Figure 7. A very rough correspondence occured between sulfate levels and distance from the Anaconda smelter which could be due to residual SO2 fallout from the smelter. The highest sulfate lakes, however, are located in moderate/highly mineralized zones which also have sulfide bearing rocks.

A list of lakes by sulfate concentration (Appendix 5) shows that the APW contains the highest 14 lakes for SO4 sampled in 1992 (ranges from 47 to 203 ueq/L). In both the SBW and CMW the highest SO4 measured was 42 ueq/L at Minor Lake in the CMW.

The lowest ANC lake in the APW is Buck Lake (12.4 ueq/L) which is much lower than any other lake in the APW. This montane lake at 6800 feet in elevation (relatively low for the APW) is small, shallow, and marshy and is not representative of most of the APW lakes. The parent material (shown on the geologic map as being in surficial deposits derived from Ybgn quartz-feldspathic and calc-silicate gneiss and migmatite) although from one of the less weatherable formations in the APW, also does not explain the low ANC for Buck lake since surficial deposits are not resistant to erosion or weathering. The APW had the 13 highest lakes for ANC measured in 1992 including Edith (1249 ueq/L), Martin (1318 ueq/L), and Johnson (1748 ueq/L). These lakes are located in surficial deposits derived from the Helena Formation which contains considerable carbonate from the interbedded argillaceous limestone. Metal chemistry results are discussed in the APW metal water and sediment section of this report.

Acid Deposition Sensitivity

Many of the lakes sampled in the SBW and the CMW, and a few in the APW are sensitive to acidification from atmospheric deposition but no lakes are presently acidic.

The Stanford et.al. (1993) report on the R1 Air Quality Screening Workshop--Aquatic Section includes screening criteria for lake sensitivity developed by a workgroup of scientists and managers. The criteria for the aquatic screening parameters measured in the 1991 sampling include:

screening parameters	screening criteria
ANC	>200 ueq/L not sensitive to acidic inputs 100-200 ueq/L minimal if any sensitivity <25 ueq/L red flag (highly sensitive)
pH	>7.3 minimal if any sensitivity 6.4-7.3 potential sensitivity <6.0 concern for pH depression
conductivity	>20 uS/cm minimal if any sensitivity 10-20 uS/cm potetial sensitivity <10 uS/cm dilute, potentially responsive
anions	total S04 + N03 (ueq/L) > 10% of total base cations may indicate the influence of acidic imputs
total phosphorous	<10 ug/L sensitive <5 ug/L indicates extremely responsive
aluminum	<50 ug/L (LAC)

Eleven lakes (10.2%) have ANC less than 25 ueq/L and 2 lakes have pH less than 6. Appendix 4 includes a list of lakes by ANC. Fourty eight lakes (44%) have less than 10 uS/cm of conductivity. All lakes measured had less than 5 ug/L of phosphorous and less than 50 ug/L of aluminum. The lab detection limits for phosphorous (0.01 ppm) were not sufficiently precise for screening criteria use at this time.

The most acid deposition sensitive lakes include Upper Libby Lake (ANC of 6.1 ueq/L) and Lower Libby (17 ueq/L) in the CMW, Buck Lake in the APW (12.4 ueq/L), and Blodgett (17.7 ueq/L) and North Kootenai (18.3 ueq/L) in the SBW. Since 1 ppm of alkalinity = 20 ueq/l of ANC, all of these lakes have less than 1 part per million of alkalinity buffering. The Upper Libby lake lake ANC of 6.1 ueq/l (field duplicate was 5.2 ueq/L, the 1991 Phase 1 measurement was 5.4 ueq/l) is close to the lowest ANC lakes measured in the WLS of 3-5 ueq/L in the Washington Cascades (Landers et.al., 1987). Both Upper Libby and Buck lakes had pH of just under 6.0 (5.98 and 5.89 respectively).

Fourty eight (42%) of the R1 (92) lakes sampled had ANC >200 ueq/L which indicates that these lakes are not sensitive to acidic inputs. In the higher ANC lakes the weathering of primary minerals (which could be accelerated with acid deposition) results in solution of calcium and magnesium and a balanced amount of bicarbonate. In lake systems which have carbonate bearing strata (such as the Precambrian belt series Wallace formation in the CMW and APW and Helena formation in the APW) increased acid deposition would be largely neutralized by increased weathering which releases base cations into solution.

The conductivity screening criteria is not consistent with the ANC criteria for dilute lakes. A revised R1 screening criteria of less than 5 uS/cm would provide a more consistent tie to the ANC screening criteria.

The anion criteria of total sulfate + nitrate <10% of base cations is frequently exceeded. In the SBW the S04+NO3/base cation ratio varies from 0.02 to 0.46. The lakes with the highest ratio (Holloway, Little Carlton, Mills, and North Kootenai) are low ANC lakes in the NE part of the wilderness area. In the CMW the S04+NO3/base cation ratios varied from 0.02 to 0.29 with the highest ratios in the low ANC Ravalli quartzite lakes. Upper Libby lake has the highest ratio of 0.29. The APW S04+NO3/base cation ratios varied from 0.01 to 0.45 with the highest sulfate values in the mineralized zones (notable the Carpp lakes area). It would appear, assuming most of the sulfate is from geologic and not atmospheric sources, that the 10% screening criteria must be used with caution since several lakes have ratios exceeding 0.10. This criteria may be most useful for a comparison of time trends in ratios for individual lakes monitored over several years.

Turk (1991) used the WLS data to compare concentrations of sulfate and chloride and wet fall concentration of SO4, NO3, and H+ in lakes with less than 200 ueq/L ANC in the Bitterroot range. Turk calculated that the maximum existing decrease in ANC would be equal to the wetfall H+ concentration of about 5 ueq/L if all of the present acidity was anthropogenic. Wetfall chemistry at the Lost Trail Pass NADP site (about 18 miles from the SE corner of the SBW), during 1990-1992 had an average pH of 5.5, SO4 of 0.22 mg/L, NO3 of 0.28 mg/L, and conductivity of 3.3 uS/cm which indicates low acidity in existing wetfall deposition (unpublished NADP data). If the 1992 Lost Trail Pass NADP deposition chemistry is representative for the SBW (currently and over the past), then it seems reasonable to conclude that most of the present acidity is not anthropogenic, and that the SBW lakes are still relatively unaffected by acid deposition.

For lake systems not experiencing acid deposition, the "standard composition" of lake water includes calcium and magnesium as the dominant cations and bicarbonate as the dominant anions (Rodhe, 1949). This generality applies to all of the 1992 R1 lakes. Although none of the R1 lakes appear to be degraded under current acid deposition levels, many of the lakes are extremely susceptible to damage from future degradation of air quality as relatively small additions of sulfuric or nitric acid deposition could cause the lakes to become acidic. The most sensitive R1 lakes have considerably less buffering capacity than many of the Adirondack lakes which have become acidified.

<u>Metals Analysis in the Anaconda Pintler Wilderness</u>

Total recoverable metals in the water column and lake sediment elemental analysis were measured in the APW and 6 adjacent lakes as a "preliminary screening" for potential "injury" from metal fallout from emissions from the old Anaconda smelters. The Anaconda smelters processed copper and zinc ore mined in Butte (27 miles east). The smelting began operations in 1882 and emissions greatly accelerated in 1902 with startup of the Washoe smelter on "Smelter Hill" which operated until closure on September 29, 1980. The smelter was 15 miles east of the APW boundary. Gelhaus et.al. (1978) estimated SO2 emissions from the smelter complex at 321,000 tons/yr which is much larger than the cumulative total of existing stationary SO2 sources in Montana (71,500 tons/yr in the unpublished 9/92 Air Quality Bureau emission inventory list). The Montana Air Quality Bureau documented consistent violations of sulfur dioxide and particulates in the Anaconda area in the 1970's (Gelhaus et.al., 1978). The MSDH (1966) reported elevated levels of arsenic, lead, total suspended particulates, and benzene in the air in Anaconda in 1961 and 1962.

Anaconda smelter photograph in the MSDH (1966) report.

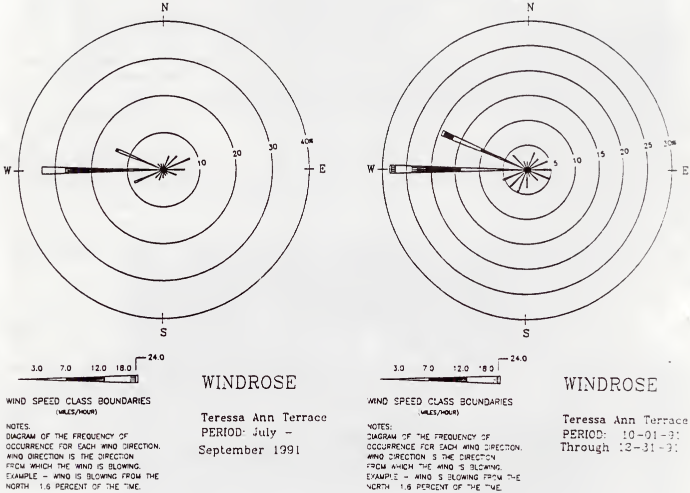


Figure 8. Unpublished wind rose information for 1991 collected on the northern edge of the city of Anaconda (Superfund Project, Solid and Hazardous Waste Bureau, DHES) shows a sharply predominant westerly wind direction which would transport smelter emissions to the east away from the APW. The wind was primarily from the west both in frequency of occurence and velocity. A gentle up valley breeze was recorded in both the July-September and October-December quarters. If these surface 1991 wind patterns are typical for the years of smelter operation (1902-1980), then potential for smelter emission contamination of the SBW lakes is limited.

Although the smelter was predominantly downwind, the amount of residual metal or sulfate (acid deposition) contamination in the APW is unknown. The 1992 monitoring of APW metals is an investigation to determine if potential exists for smelter related metal injury to lake water and sediments and to determine if a more detailed "pre-assessment screen" is warranted. This part of the 1992 R1 synoptic lake surveys was funded by the National Resource Damage Assessment, Federal Facilities Compliance Program.

Appendix 6 includes a listing of all of the total recoverable metals (unfiltered) in lake water for 8 metal parameters in each of the 39 APW lakes and 6 lakes in the Deerlodge NF adjacent to the APW. The concentrations of these metals are very low relative to Clark Fork River metal values, also being monitoried as part of the NRDA/CERCLA program.

Two literature sources can be used to put the APW 1992 metal water data in perspective. Forstner (1984) lists typical background values of trace metals for <u>filtered</u> samples in freshwater. Since much of the metals in lake water are typically associated with small suspended sediment particles, phytoplankton, zooplankton, and organic matter, filtered metal measurements would be expected to be lower than total recoverable metals. Some guidance for total recoverable metals in freshwater is given in EPA (1986) for freshwater chronic criteria. adjusted for hardness of 25 mg/l. Higher numbers in the EPA criteria for acute standards were not used since the reported values are assumed to represent chronic (long term) conditions.

	-------concentrations in ug/L-------						
	Be	Fe	Cu	Zn	As	Cd	Pb
Background values Forstner (1984) filterted	0.01	<30	2	10	2	0.07	0.2
EPA (1986) freshwater chronic criteria total recoverable	5.3	1000	3.6	10.1	48	0.4	0.5

The 1992 R1 APW metal concentrations are below the 1986 EPA freshwater chronic criteria for beryllium, iron, zinc, and arsenic. In fact many of the lakes have total recoverable values below the typical "filtered" values reported by Forstner (1984). Exceedences of the EPA (1986) criteria occur for Carpp lake for zinc (136.3 ug/L), cadmium at Buck Lake (2.82 ug/L) Hope Lake (5.27 ug/L), and Unnamed lake (6.57 ug/L). Lead exceedences of the EPA (1986) criteria occurred at Lake of the Isle (4.13 ug/L), Fourmile (1.07 ug/L), Hope (1.23 ug/L), and Ten Mile Lake (1.54 ug/L). Mystic (8.01 ug/L), Nelson (4.79 ug/L), and Ten Mile (5.53 ug/L) exceeded the copper criteria.

The "elevated" cadmium levels occur in lakes in the southwest part of the APW and are probably not related to smelter emissions. The relatively high zinc value at Carpp Lake is probably attributable to the high mineral potential in the Carpp Creek watershed which will be discussed in the lake sediment section. The "elevated" zinc values for most of the lakes are suspect since zinc recovery in the laboratory was above the spike tolerance range which indictes probable contamination from laboratory reagents and/or glassware. Three of the 4 highest lead values, however, occured in the NE part of the APW including an exceedence of the EPA (1986) lead criteria at Lake of the Isle (4.13 ug/L) which was the closest measured lake to the Anaconda smelter.

The lake sediment core sample data (Appendix 7) were developed using nitrogen peroxide digestion and ICP-MS scanning. This technique (EPA Method 6020), was sporadically effective for a Priority Pollutant/CLP quality control dry soil standard for which recovery varied from 19% to 160% with 67% of the elements in the advisory range. However this technique did not provide sufficient recovery for the APW sediment samples. Subsamples of the homogenized original samples were therefore re-evaluated using a more thorough technique of drying the samples and seiving through a 0.3 mm mesh nylon screen and pre-digesting with H2O2, placed in an ultrasonic bath for 2 hours (to facilitate breakdown of the organics), digestion with aqua regia (HCl and NNO3 acid), microwave heating, centrifuging, and analysis on an ICAP. The more extensive digestion and extraction technique resulted in much higher metal recovery. The values are reported in Appendix 8 for the 12 metals of concern. The Appendix 8 values range from 2 to 228 times higher than the Appendix 7 values; typically 5 to 20 times higher. The Appendix 8 values, therefore, are assumed to be more accurate, and will be used in the rest of this lake sediment metal discussion.

Interpretation of the 1992 APW lake sediment data (Appendix 8) must be qualified with the caution that several sampling design limitations constrain the conclusivness of the information in linking metals in lake sediments to Anaconda smelter emissions. These include:

1) The samples were collected in various parts of the nine lakes at depths limited by the length of the core sampler. Maximum water depth in the areas sampled was only about 10 feet. Renberg (1984) demonstrated that the best part of a lake to collect sediment core samples is in the deepest section where lake sediments are less disturbed by wave action and aerobic decomposition at the water/sediment interface.

2) The amount of sample collected (depth of core) was not consistent. Sample depth varied from about 1" to 6" with average depth of about 3". Moore (1992, personal communication) and Eilers (1992, personal communication) cautioned that in low sedimentation rate lakes like the APW, potentially contaminated lake sediments would be expected to occur in the upper 1-2 cm (0.4 to 0.8 inches) although mobility of metal elements in the lake sediment varies. Norton (1986a) shows sediment cores from the Wind River Mountains in Wyoming (data back to 1700 with Pb 210) which indicates lead contamination is isolated to the upper 5cm (2"). By collecting lake sediment "core grab samples", the 1992 samples could have "diluted" the upper potentially contaminated sediments with underlying uncontaminated sediments.

3) Particle size in the APW sediment cores varied substantially from silt to sandy silt and was not measured. A strong relationship exists between grain

size and the amount of metals (Moore, 1992, personal communication) with high metal concentrations usually more prevalent in finer grained lake sediment in the center of a lake.

4) Typically, lake sediment analyses to detect presence or absence of metal contamination uses a wider diameter core sampler (for less sediment compression), pulling up the sample intact (with box or freeze cores), and conducting the chemical analysis at 2-3 mm (0.2-0.3 cm) intervals. This allows comparison of potentially contaminated surface sediment with uncontaminated deeper lake sediments.

Quality criteria do not exist for lake sediments, however the AP 92 data can be compared to Forstner (1983) which lists background and maximum contaminated values of lake sediments for midwestern lakes.

Table 38. Distribution of minor elements in sedimentary profiles from Lake Michigan (Ruch et al., 1970; Shimp et al., 1971; Kennedy et al., 1971; Frye and Shimp, 1973), Lake Monona/Wisconsin (Lake Minocqua) (Shukla et al., 1972; Syers et al., 1973; Iskandar and Keeney, 1974), Lake Washington (Barnes and Schell, 1973; Crecelius and Piper, 1973; Schell, 1974; Crecelius, 1975), and Lake Erie (Walters et al. 1974). Data of background and maximum value in parts per million (ppm). F = factor of enrichment

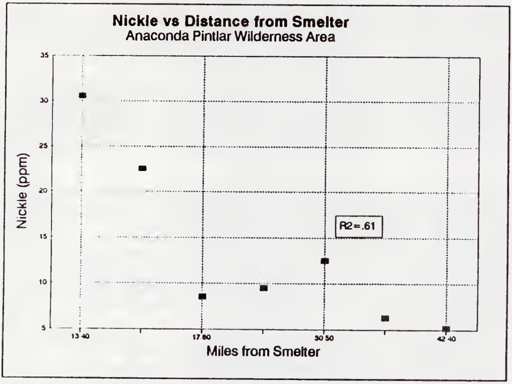
	Lake Michigan			Wisconsin Lakes			Lake Washington			Lake Erie		
	back-ground	max. value	F	back-ground	max. value	F	back-ground	max. value	F	back-ground	max. value	F
Zinc	120	317	*2,5*	15	92	*6*	60	230	*4*	7	42	*6*
Chromium	77	85	*1*	7	49	*7*		n.d.		13	42	*4.5*
Nickel	54	44	*1*	34	50	*1.5*	(iron:		*1*)	40	95	*2.5*
Copper	44	75	*1.5*	22	268	*12*	16	50	*3*	18	59	*4*
Lead	40	145	*3.5*	14	124	*9*	20	400	*20*		n.d.	
Arsenic	11	22	*2*	(2	51	*25*)	10	200	*20*	0.6	3.2	*5.5*
Mercury	0.04	0.2	*5*	0.24	1.12	*5*	0.1	1.0	*10*	0.004	4.48	*12*
Cadmium		n.d.	*2.5*	2.5	4.6	*2*		n.d.		0.14	2.4	*17*

Severson et.al.(1987) lists metal concentrations for sediment in a few rivers in Wyoming and Montana.

River	Arsenic ppm	Copper ppm	Lead ppm	Zinc ppm
Sun River, Montana	8.7	31.2	17.3	11.2
Mile River, Montana	6.3	35.6	15.7	86.4
Kendrick, Wyoming	7.0	17.7	18.3	79.2

A precise comparison of the Forstner (1983) and Severson (1987) data to the 92 APW sediment data should be based on identical lab procedures. Nevertheless, cadmium values in the APW lakes appear to be "normal" except for a high value of 7.68 at Upper Carpp lake. Chromium values appear to be normal. Copper and zinc are also within a "normal range" except for the elevated values reported at Upper Carpp lake. Lead values appear to be elevated at all of the sites particularly at Upper Carpp lake.

Long and Morgan (1991), in a review of sediment/metals data, indicated that probable biological effects are likely with cadmium levels of 9 ppm, copper of 390 ppm, lead of 300 pm, and zinc of 270 ppm. The only lake with measured sediment metals which exceed this criteria was upper Carpp lake for lead and zinc. If the 92 procedure had isolated lake sediments contaminated during the smelter operation, the levels could have been higher.



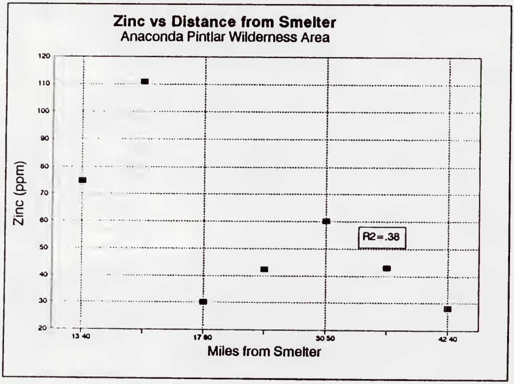


Figure 8. Excluding the Upper Carpp Lake data and regressing metal sediment concentrations vs distance from the smelter results in fair correlation of measured sediment concentrations for nickel and zinc. Cadmium ($R2=0.65$) and copper ($R2=0.62$) also had a similar relationship.

A "finding" of a relationship between proximity to the smelter and lake sediment metal concentrations, however, must be tempered by an examination of mineralized zones within the APW. As mentioned in the Geology/Geochemistry section of this report, the APW geology is primarily sedimentary rock of Middle Precambrian to Paleozoic age, and igneous intrusives (mostly granodiorite to granitic) of Cretaceous to Tertiary age. Elliot et.al. (1985) used digitally processed Landsat multispectral scanner analysis, geophysical investigations, geochemical analysis of stream sediment and rock samples, and field investigations to identify seven areas of moderately to high reserve potential in the APW.

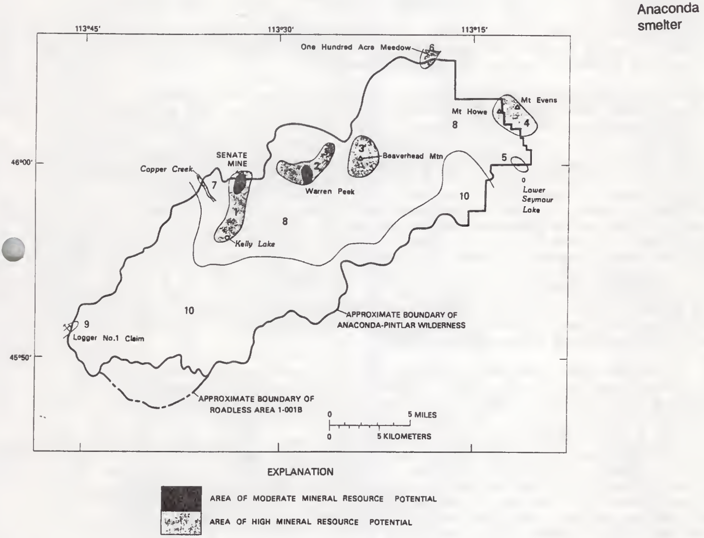


Figure 9. Moderate and high mineral resorce potential of the APW from Elliott et.al, (1985). All of the limonitic rock (hydrothermally altered) which contains anomalously high concentrations of metal are located in the central and NE part of the APW which complicates the comparison of lake metal sediments with proximity to the Anaconda smelter.

Upper Carpp Lake is located within the Warren Peak high mineral resource area (area 2 figure 9) with mesothermal veins, porphyry, and stock works deposits with "favorable" mineralized geology consisting of granodiorite intruded into siliceous and calcareous sediments. The base parent material is shown on the map as TKgd, Tertiary to Cretaceous biotite and granodiorite. The limonite mapping found occurances of hydrothermal alteral rock and high concentrations of silver, lead, copper, zinc, and molybdenum.

Stentz (1975), in a report on mineral and metal resources for the upper Rock Creek area of the Deerlodge NF, identified the Upper Carpp Creek as a mineralized area with veins of copper, silver, and lead. The old Carpp mine has partially developed reserves of silver, lead, and copper about 3 miles to the north (1 mile from the APW boundary). Six ridges with peaks of over 9000 feet seperate the Carpp Lakes area from the predominantly downwind Anaconda smelter.

It seems probable that the "elevated" levels of metals at Upper Carpp lake are directly related to the high concentrations of metals deposited into the Upper Carpp lake watershed and not the Anaconda smelter.

The 2 lakes with sediment cores sampled closest to the Anaconda smelter (Lake of the Isle at 13.4 miles and Upper Twin lakes at 10.5 miles) had relatively high concentrations of cadmium, copper, nickel, lead, tungsten, and zinc relative to the non-Carpp lakes further from the smelter (Appendix 8). These 2 lakes, however, are located just downstream from the Mount Evans area of high mineral resource potential (area 4 in Figure 9). The Mount Howe/Mount Evans area is shown in Elliot (1985) as having a large amount of hydrothermally altered rock and a mineralized geologic zone ("moderate mineral potential zone") of contact metamorphosed quartzite and argillite, quartzite, and argillite with concentrations of dikes and quartz veins and widespread altered rock. Elevated geochemical anomalies of berylium, silver, copper, arsenic, zinc, tungsten, and floride were measured in rock samples although no identified mining resources (economic veins) were reported. It is probable that the higher concentrations of metals in the lake sediments of Lake of the Isle and Upper Twin Lake are due to sediments washed in from mineralized deposits in the Mount Howe-Mount Evans mineral compex.

It is possible that some lead contamination in the lake sediments has occurred from the smelter. Such a hypothesis would tend to be supported by the water water column lead data (total recoverable) in Appendix 6. Three of the five lakes with lead concentrations above mdl and the EPA (1986) level criteria of 0.5 ug/L were located closest to the smelter (Fourmile, Lake of the Isle, and Tenmile). Norton (1986b and 1986c) documented increased lead in sediment cores from 10 lakes in the Adirondack Mountains of NY. These lakes had background levels of lead (from deep sediments) from 15-65 ppm and surface contamination of lead from 299 to 759 ppm. Norton attributes the increase to coal burning, sulfide ore smelting, and lead additions to gasoline. Baron et.al., (1986) reported elevated lead in the upper parts of lake sediment in 4 lakes in Rocky Mountain National Park in Colorado (maximum concentrations of 300 ppm). The lead increase started in the middle to late 1800's which Baron speculates is directly attributable to particulate matter fallout from the mining industry which began in the mid-1800's. Historical accounts of mining related air pollution has been documented in the area. The Appendix 8 lead concentrations, (with upper Carpp lake excluded) had an $R2=0.46$ when regressed against distance from the smelter. Johnson lake, at 30.5 miles from the smelter, had higher lead

in the lake sediments (228 ppb) than either Lake of the Isle (13.4 miles) or Upper Twin lake (14.5 miles). Carrigan (personal correspondence) in the assessment work for Anaconda smelter, has found high levels of arsenic, copper, zinc, and cadmium in soils, surface and groundwater, and flue dust in the Anaconda smelter area but not particularly high levels of lead. Therefore, a hypothesis of elevated lead levels in the lakes close to the smelter is not consistently supported by the 1992 data or historical information.

Based on available data, emissions from the Anaconda smelter cannot be conclusively linked to metal concentrations in the lake sediments. The highest levels of lake sediment metals measured, in the Carpp lake area, are probably a result of the highly mineralized nature of the Carpp lake watershed. Jonnie Moore (personnel correspondence) indicated that in his soil investigations around the Anaconda smelter, metal contamination in soils has been measured in a 20 mile radius from the smelter, but at much reduced levels of contamination further than 6 miles from the smelter. Carrigan (personal correspondence), indicated that the smelter assessment work has found the bulk of the soil contamination from the smelter to be 8-10 miles NE and easterly although he doesn't have a good data grid to the west.

With the exception of lead and zinc in the Upper Carpp lake sediments, which exceed Long and Morgan's (1991) "probable biological effects" criteria, none of the lake sediment analysis has detected concentrations which could be considered injurious to the aquatic organisms or could be considered "injury" in context of the NRDA/FFCP/CERCLA program.

To fully resolve the background vs recent sediment metal contamination question, a more intensive lake sampling effort could be conducted. Moore (personal communication) recommended the following potential program:

* 3 shallow core samples at 1-2 cm depths in each of 20 lakes in the APW with samples analyzed with a intensive digestion/extraction technique for about 15 metal parameters. A few lakes on private land closer to the smelter could also be sampled.

* filtered and total recoverable metal water chemistry analysis at the 20 lakes for Be, Mn, Cu, Zn, As, Cd, and Pb.

* box core sediment sample at 4 lakes with with metal analysis using intensive digestion/extraction/ICP technique at 2 mm (0.2 cm) intervals. Potential lakes include Upper Twin, Upper Seymour, Upper Carpp, and Mystic lakes.

* measure grain size and organic and total carbon content of the 4 box core samples.

The analysis should include a detailed evaluation of the CERCLA assessment of the contaminated soils and flue dust around the smelter to compare with recent lake sediment chemistry.

Total estimated cost of the above analysis would be between $20,000 and $30,000.

4. PHASE 3 LAKES

Selection Criteria

Six criteria were used to tentatively identify 10 lakes for long term benchmark (Phase 3) monitoring including:

1) Low ANC and conductivity

2) Lakes should have representative chemistry for low ANC lakes in the wilderness area, and representative depth and morphometry for all lakes.

3) Relatively low dissolved sulfate from watershed sources. Ideally sulfate + nitrate should be <10% of the sum of base cations.

4) Reasonable trail access

5) No obvious man caused effects such as impoundments and fluxuating water levels, or historical mining activities in the watershed

6) The lake should be upstream of all other lakes in the watershed, and with a non-complex watershed to facilitate future lake/watershed chemistry modeling.

Tentative Phase 3 Lakes

Lakes which were tentatively selected as Phase 3 lakes and primary reasons for selection include:

Wilderness	Forest	Lake	Reasons
Selway Bitterroot	Bitterroot	North Kootenai	low ANC (24 ueq/L), good access, no dams, low SO4: base cation ratio (0.06).
Selway Bitterroot	Bitterroot	Big Grizzly	low ANC (33.4), good access, no dams, low SO4:BC ratio (.09)
Selway Bitterroot	Clearwater	South Colt	low ANC (40.9), good access, representative of lakes in the NW SBW in the Clearwater NF
Selway Bitterroot	Nez Perce	Shasta	low ANC (24), lowest ANC lake in the SW part of the SBW
Cabinet Mountains	Kootenai	Upper Libby	very low ANC (6.5)--lowest measured in R1, near NORANDA mining project, access strenous
Cabinet Mountains	Kootenai	Lower Libby	low ANC (17 ueq/L), would compliment Upper Libby
Cabinet Mountains	Kootenai	Engle	low ANC (35.7), good access

Anaconda Pintler	Deerlodge	Unnamed T3NR15WS16	good access, low SO4:BC ratio
Anaconda Pintler	Deerlodge	Ivanhoe	relatively low ANC in APW (112) good access, relatively low SO4:BC ratio for AP (0.11)
Anaconda Pintler	Beaverhead	Upper Lost	one of the few APW lakes timberline, non-complex watershed for chemistry modeling, relatively low SO4:BC ratio for APW (0.13)

North Kootenai lake in the Selway Bitterroot Wilderness, a recommended Phase 3 lake.

The final selection of Phase 3 monitoring lakes will be completed in the AQRV monitoring plans for each wilderness area (Cabinet Mountains in 1993, Selway Bitterroot in 1994, Anaconda Pintler in 1995).

Recommended Phase 3 Parameters

Phase 3 monitoring should be designed to provide a long term benchmark to evaluate trends in acid deposition and other atmospheric related changes in the lake ecosystems. The primary focus is on chemistry data but supportive physical characterization and documentation of biological organisms is recommended. The Phase 3 data should allow a long term check on the lake ecological stability

and support a specific calibration of each Phase 3 lake and watershed to the MAGIC model (Eilers et.al., 1991c). The MAGIC model can be used by the Forest Service to estimate chemical effects on lakes from proposed upwind emission increases as part of the PSD permit application and analysis process.

Phase 3 recommended methods and parameters include:

1) Collect samples in a raft in the middle of each lake

2) Run a temperature profile

3) Measure "Phase 2" chemical parameters (pH, conductivity, Ca, Mg, Na, K, NH4+, F, NO3, SO4, ANC, SiO2, P, Al, gran alkalinity, calculate ANC). Use better precision for P and F than in 1992. Include duplicates and field blanks.

4) Total Kjeldahl nitrogen (organic nitrogen), organic carbon (dissolved or total), and summer measurement of trichromatic chlorophyl A.

5) Periodic measurements (at least 2X in the first 7 years) of phytoplankton. This could consist of a 500 ml sample and a qualitative identification of major photoplankton (mainly diatoms) species.

6) Sample frequency should be twice yearly, including early as possible (late June or early July) and the fall overturn period (late September to early October).

7) Duration of sampling should be a minimum of 7-10 years until a clear trend is established.

8) Data should be plotted each year and laboratory results evaluated to insure lab reporting consistency and for statistical trend analysis.

Watershed and Lake Chemistry Modeling

The Phase 3 lake data can be linked directly into the R1 Forest Service air regulatory process cabability by calibrating each Phase 3 lake to the MAGIC model (Eilers et.al., 1991c). The MAGIC (Model of Acidification of Groundwater in Catchments) was used in the R1 1991 Screening Workshop (Stanford et.al., 1993) for a tentative assessment of acid deposition sensitivity of 12 R1 lakes in the Absaroka Beartooth, Selway Bitterroot, and Bob Marshall Wilderness Areas. The MAGIC model calibration consists of adjusting model coefficients through an optimization process using watershed factors, soil information, atmospheric deposition chemistry, and lake chemistry. Once a lake is calibrated to its watershed and atmospheric deposition input factors, lake chemistry response can be hindcast and forecast to allow input of potential changes in atmospheric deposition and prediction of associated changes in lake chemistry. This is potentially a very useful tool in (Prevention of Significant Deterioriation) PSD applications. For example, emissions from a proposed mine, smelter, or industrial facility upwind of the Cabinet Mountains Wilderness could be run through a dispersion model to estimate changes in the atmospheric deposition loading rates at Libby lakes. This "changed" deposition would then be input to the MAGIC model to estimate changes in the water chemistry at Upper and Lower Libby lakes. These potential changes would then be compared to the Screening Criteria discused in the Acid Deposition Sensitivity part of this

report (Stanford et.al., 1993), and a decision made if an adverse impact determination is appropriate. Information which would be needed for a specific MAGIC calibration of each Phase 3 lake includes:

1) at least 2 years of Phase 3 lake chemistry information

2) soil "survey" of soil depth, cation exchange capacity (Ca, Mg, Na, K), base saturation, soil pH, bulk density, and porosity for each of the major soil types in the lake watershed above the lake

3) map of rock outcrops, permanent snow fields, and vegetation in the lake watershed

4) characterization of dominant rock minerals

5) plot of stream network upstream of the lake

6) lake depth profile

7) measurements of discharge at inlet(s) and outlet through a range of discharges, including the peak of snowmelt runoff

8) pH, ANC and sulfate in inflowing streams

9) average annual precipitation

10) charactization of depositon chemistry. This could be done by collecting spring snow cores and comparing with snow cores collected at the NADP site at Lost Trail Pass for the SBW and APW and at Glacier National Park for the CMW.

The MAGIC model calibration is not useful for lakes higher that 50 ueq/l of ANC since higher ANC lakes would not likely be acidified in any reasonably forseeable acid deposition scenario. This factor would probably negate the need to conduct MAGIC model calibration in the Anaconda Pintler Wilderness .

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Appendix 1. 1992 Synoptic Water Chemistry from Anaconda-Pintlar, Cabinet Mountains, and Selway Bitterroot Wilderness Areas Displayed in mg/L

FS			lab	uS/cm	MG/L									UEQ/L	MG/L	MG/L	UG/L
ID#	LAKE	WA	pH	Conduct.	Ca	Mg	Na	K	NH4	F	Cl	NO3	SO4	ANC	SiO2	P	Al
MS210	BUCK	APW	5.893	8	0.314	0.162	0.554	0.546	0.073	0.000	0.250	0.000	1.269	12	0.355	0.000	9.375
MS189	CARPP	APW	7.089	41	4.677	0.680	1.394	0.334	0.041	0.000	0.180	0.000	7.926	198	8.593	0.000	23.870
MS213	CRYSTAL	APW	6.963	15	1.470	0.275	1.934	0.477	0.000	0.000	0.234	0.000	0.291	128	4.565	0.000	20.775
MS224	EDITH	APW	8.146	108	21.546	1.609	0.750	1.893	0.028	0.000	0.229	0.000	2.465	1249	5.106	0.000	7.007
MS153	FLOWER	APW	7.690	55	7.811	1.579	0.716	1.172	0.047	0.000	0.496	0.538	1.930	554	3.326	0.000	17.205
MS223	HICKS	APW	7.060	26	3.345	0.425	0.801	0.176	0.000	0.000	0.212	0.000	1.133	214	3.693	0.000	9.922
MS246	HIDDEN	APW	8.258	97	20.209	1.337	0.471	1.554	0.028	0.000	0.190	0.000	3.358	947	2.101	0.000	16.103
MS211	HOPE	APW	7.011	15	1.336	0.275	1.834	0.616	0.000	0.000	0.566	0.000	0.546	120	6.464	0.000	8.779
MS161	IVANHOE	APW	6.621	13	1.672	0.525	0.254	0.387	0.032	0.000	0.151	0.272	0.833	113	3.382	0.000	9.959
MS146	JOHNSON	APW	8.234	140	29.270	2.842	0.498	1.722	0.098	0.000	0.100	0.000	1.673	1748	3.548	0.104	21.043
MS245	KELLY	APW	8.788	75	13.080	1.774	0.647	0.775	0.039	0.000	0.335	0.000	0.230	760	4.364	0.000	35.913
MS227	LAMARCHE	APW	6.868	14	1.690	0.607	0.557	0.544	0.021	0.000	0.148	0.021	1.594	109	3.946	0.000	14.330
MS214	LION	APW	7.159	21	2.202	0.350	2.320	0.801	0.000	0.000	0.392	0.000	0.812	185	8.044	0.000	12.119
MS173	LITTLE JOHNSON	APW	8.848	99	17.040	3.981	0.571	0.994	0.033	0.000	0.588	0.027	0.381	1187	0.633	0.000	43.012
MS217	LITTLE RAINBOW	APW	7.468	34	5.154	0.363	0.361	0.315	0.000	0.000	0.134	0.000	2.313	265	1.110	0.000	40.152
MS228	LOST #1	APW	6.937	14	2.504	0.177	0.551	0.314	0.027	0.000	0.204	0.043	1.082	125	1.319	0.000	5.309
MS229	LOST #2	APW	7.015	26	2.851	0.159	1.152	1.780	0.096	0.000	1.348	0.110	1.069	150	0.670	0.000	2.767
MS190	LOWER CARPP	APW	7.062	41	4.439	0.657	1.414	0.456	0.056	0.000	0.213	0.000	7.394	206	6.841	0.000	18.976
MS147	MARTIN	APW	8.160	109	22.560	1.936	0.379	1.471	0.062	0.000	0.146	0.000	1.453	1319	2.494	0.000	18.381
MS212	MYSTIC	APW	7.057	13	1.390	0.212	1.487	0.199	0.000	0.000	0.106	0.000	0.376	116	5.856	0.000	5.440
MS249	OREOMNOS	APW	8.038	89	17.243	1.385	0.393	0.809	0.028	0.000	0.241	0.000	0.663	889	1.929	0.000	16.314
MS152	PAGE	APW	8.414	97	19.310	2.185	0.448	1.052	0.029	0.000	0.202	0.000	2.536	1144	1.888	0.000	17.452
MS171	PHYLLIS	APW	7.378	48	4.264	1.476	1.021	1.617	0.119	0.000	1.562	0.036	0.468	446	2.264	0.066	18.898
MS145	RAINBOW	APW	7.821	59	11.450	0.702	0.448	1.041	0.080	0.000	0.100	0.000	1.232	697	3.046	0.000	21.586
MS244	RIPPLE	APW	7.768	71	12.453	1.560	0.756	0.758	0.028	0.000	0.319	0.000	1.756	686	6.187	0.000	20.314
MS247	SAWED CABIN	APW	8.055	78	14.663	1.133	0.471	1.080	0.028	0.000	0.241	0.000	0.942	772	3.833	0.000	23.467
MS208	SURPRISE	APW	7.283	28	4.401	0.137	0.801	0.153	0.080	0.000	0.136	0.000	0.355	236	3.970	0.000	20.610
MS233	TAMARACK	APW	6.914	17	2.644	0.363	0.430	0.685	0.000	0.000	0.241	0.000	1.120	139	1.985	0.000	1.379
MS170	UNNAMED	APW	7.030	13	1.715	0.448	0.293	0.407	0.022	0.000	0.134	0.000	0.530	137	2.816	0.060	10.833
MS172	UNNAMED	APW	7.142	20	2.540	0.732	0.426	0.276	0.033	0.000	0.127	0.017	0.387	216	2.437	0.066	19.922
MS150	UNNAMED	APW	6.815	6	0.946	0.139	0.303	0.300	0.040	0.000	0.130	0.616	0.479	46	2.440	0.000	6.096
MS191	UNNAMED T3NR15WS2	APW	6.876	33	2.794	0.447	1.449	1.036	0.100	0.000	0.556	0.120	5.693	134	5.698	0.000	13.607
MS248	UNNAMED T2NR15WSE	APW	7.555	38	6.307	0.530	0.350	0.758	0.028	0.000	0.394	0.000	0.243	319	0.118	0.000	23.139
MS234	UNNAMED T3NR15WSE	APW	6.999	28	2.923	0.563	1.202	0.732	0.073	0.000	0.319	0.000	2.710	156	5.325	0.000	4.829
MS192	UNNAMED T3NR15WSE	APW	7.737	44	7.198	0.192	0.289	0.334	0.061	0.000	0.254	0.529	0.961	420	1.232	0.000	17.044
MS188	UPPER CARPP	APW	6.810	17	2.446	0.282	0.597	0.212	0.000	0.000	0.069	0.000	2.758	116	3.633	0.000	13.761
MS151	UPPER SEYMOUR	APW	7.942	59	10.297	0.611	0.578	0.682	0.014	0.000	0.080	0.000	2.242	634	4.461	0.000	11.011
MS209	VIOLET	APW	7.109	27	3.600	0.237	1.356	0.176	0.087	0.000	0.109	0.000	0.323	226	2.693	0.000	16.458
MS263	WARREN	APW	7.097	14	2.582	0.287	0.566	0.246	0.012	0.000	0.161	0.000	1.033	124	2.748	0.000	20.216
MS163	LAKE OF THE ISLE	near AP	6.668	36	4.720	0.690	1.320	0.832	0.017	0.000	0.146	0.015	6.151	163	9.256	0.000	36.036
MS144	STORM LAKE	near AP	7.927	95	19.310	1.540	0.640	0.658	0.186	0.000	0.125	0.000	2.536	1067	4.403	0.701	19.980
MS175	UPPER FOURMILE BAS	near AP	7.051	16	2.171	0.298	0.437	0.364	0.018	0.000	0.133	0.000	1.119	145	2.297	0.000	10.512
MS262	UPPER NELSON	near AP	7.181	33	4.616	0.510	0.833	0.748	0.017	1.956	0.156	0.000	3.866	147	4.134	0.000	4.491
MS264	UPPER TENMILE	near AP	7.041	12	1.932	0.116	0.859	0.261	0.012	0.000	0.323	0.000	0.727	91	2.609	0.000	10.164
MS162	UPPER TWIN	near AP	7.447	64	10.090	1.390	0.840	0.750	0.021	0.000	0.111	0.000	9.748	471	7.315	0.000	30.709

Appendix 1. 1992 Synoptic Water Chemistry from Anaconda-Pintlar, Cabinet Mountains, and Selway Bitterroot Wilderness Areas Displayed in mg/L

FS ID#	LAKE	WA	lab pH	uS/cm Conduct.	MG/L Ca	MG/L Mg	MG/L Na	MG/L K	MG/L NH4	MG/L F	MG/L Cl	MG/L NO3	MG/L SO4	UEQ/L ANC	MG/L SiO2	MG/L P	UG/L Al
MS199	BAREE	CMW	6.686	8	0.695	0.192	0.546	0.120	0.036	0.000	0.126	0.000	0.886	51	3.090	0.000	8.628
MS230	DOUBLE	CMW	6.967	11	3.202	0.470	0.472	0.248	0.027	0.000	0.081	0.000	0.916	145	1.386	0.000	13.661
MS260	ENGLE	CMW	6.558	6	0.748	0.125	0.422	0.189	0.000	0.000	0.273	0.026	0.380	36	3.611	0.000	8.095
MS182	GRANITE	CMW	7.399	40	4.706	1.855	0.178	0.151	0.022	0.000	0.072	0.191	1.333	405	1.289	0.000	16.685
MS206	LEIGH	CMW	6.872	9	1.303	0.403	0.209	0.104	0.041	0.000	0.155	0.000	0.426	85	1.220	0.000	6.938
MS197	LOWER BRAMLET	CMW	6.349	5	0.252	0.072	0.370	0.090	0.027	0.000	0.116	0.000	0.302	24	3.149	0.000	7.231
MS159	LOWER LIBBY	CMW	6.375	3	0.248	0.061	0.173	0.059	0.010	0.000	0.041	0.000	0.247	17	1.483	0.000	8.347
MS215	LOWER SKY	CMW	7.535	30	3.999	0.914	0.508	0.477	0.000	0.000	0.163	0.000	0.960	257	3.407	0.000	17.281
MS205	MINOR	CMW	7.649	54	6.810	1.288	0.568	0.452	0.035	0.000	0.187	0.000	2.028	520	2.823	0.000	28.783
MS259	MORAN BASIN	CMW	7.040	21	3.317	1.161	0.315	0.289	0.044	0.000	0.190	0.000	0.000	217	0.418	0.000	6.881
MS258	ROCK	CMW	6.846	8	1.118	0.322	0.320	0.146	0.000	0.000	0.211	0.000	0.283	60	1.211	0.000	4.529
MS198	UPPER BRAMLET	CMW	6.411	5	0.397	0.072	0.340	0.105	0.022	0.000	0.116	0.000	0.376	27	2.698	0.000	5.589
MS207	UPPER CEDAR	CMW	6.969	17	2.174	1.215	0.269	0.222	0.039	0.000	0.183	0.000	0.657	162	2.141	0.000	11.089
MS180	UPPER GEIGER	CMW	6.473	6	0.592	0.087	0.385	0.120	0.022	0.000	0.143	0.000	0.344	51	2.890	0.000	5.570
MS157	UPPER LIBBY	CMW	5.983	2	0.091	0.012	0.142	0.059	0.028	0.000	0.076	0.000	0.219	6	0.948	0.000	6.390
MS216	UPPER SKY	CMW	7.959	59	8.653	2.093	0.245	0.871	0.046	0.000	0.170	0.000	0.601	627	4.362	0.000	11.237
MS231	UPPER VIMY	CMW	6.929	39	4.011	0.461	2.573	1.022	0.102	0.000	2.985	0.000	1.569	181	1.503	0.000	11.817
MS221	BIG CREEK	SBW	6.384	7	0.788	0.087	0.369	0.338	0.060	0.000	0.253	0.000	0.455	41	2.332	0.000	5.733
MS148	BIG CREEK	SBW	6.513	5	0.583	0.139	0.311	0.085	0.025	0.000	0.054	0.043	0.387	28	2.060	0.000	8.650
MS256	BIG GRIZZLY	SBW	6.570	6	0.496	0.099	0.376	0.361	0.003	0.000	0.194	0.000	0.255	33	2.484	0.000	15.942
MS169	BILL'S	SBW	6.643	5	0.498	0.044	0.319	0.060	0.018	0.000	0.051	0.036	0.306	36	2.742	0.066	7.821
MS167	BLODGETT	SBW	6.015	3	0.183	0.026	0.192	0.051	0.044	0.000	0.113	0.000	0.238	18	1.656	0.000	6.910
MS195	BOULDER	SBW	6.622	12	1.225	0.079	0.723	0.609	0.041	0.000	0.688	0.000	0.610	78	2.464	0.000	12.216
MS251	BUCK	SBW	6.810	10	1.098	0.199	1.064	0.165	0.000	0.000	0.112	0.000	0.129	84	2.784	0.000	2.679
MS220	CANYON	SBW	6.384	9	0.865	0.074	0.747	0.546	0.299	0.000	0.603	0.000	0.383	47	2.247	0.000	1.744
MS236	CARLTON	SBW	6.434	7	0.290	0.119	0.685	0.215	0.017	0.000	0.182	0.000	1.349	21	3.567	0.000	3.150
MS193	CRYSTAL	SBW	7.031	18	2.526	0.132	0.804	0.456	0.041	0.000	0.287	0.000	0.929	160	3.666	0.000	10.648
MS196	EAGLE MTN.	SBW	6.712	5	0.397	0.049	0.330	0.090	0.022	0.000	0.086	0.000	0.121	39	3.227	0.000	8.233
MS168	EMERALD	SBW	6.653	5	0.601	0.044	0.334	0.072	0.007	0.000	0.064	0.036	0.306	35	2.387	0.000	5.013
MS225	FISH LAKE	SBW	6.591	5	0.664	0.104	0.460	0.116	0.027	0.000	0.084	0.000	0.262	40	2.054	0.000	3.353
MS242	FRED BURR	SBW	6.590	8	0.801	0.083	0.719	0.400	0.042	0.000	0.617	0.000	0.307	39	1.545	0.000	4.665
MS185	GEM LAKE	SBW	6.706	9	1.020	0.079	0.496	0.227	0.032	0.000	0.149	0.191	0.206	80	2.895	0.000	7.103
MS240	HEINRICH	SBW	6.500	7	0.617	0.055	0.714	0.369	0.017	0.000	0.707	0.000	0.078	28	1.362	0.000	4.180
MS238	HOLLOWAY	SBW	6.481	8	0.863	0.156	0.363	0.292	0.007	0.000	0.104	0.000	1.782	25	2.107	0.000	0.089
MS178	KETTLE	SBW	6.321	5	0.473	0.049	0.209	0.120	0.000	0.000	0.133	0.156	0.185	35	1.172	0.126	4.871
MS235	LITTLE CARLTON	SBW	6.373	9	0.440	0.119	1.205	0.431	0.032	0.000	0.692	0.000	1.222	30	4.152	0.000	6.118
MS243	LITTLE GRIZZLY	SBW	6.602	5	0.538	0.101	0.329	0.276	0.007	0.000	0.139	0.000	0.294	28	2.182	0.000	7.861
MS241	LOCKWOOD	SBW	6.528	6	0.698	0.083	0.488	0.261	0.052	0.000	0.355	0.000	0.218	38	2.402	0.000	7.497
MS203	LOTTIE #1	SBW	6.504	6	0.712	0.079	0.617	0.104	0.023	0.000	0.062	0.000	0.121	45	2.376	0.000	10.617
MS204	LOTTIE #2	SBW	6.514	7	0.760	0.089	0.745	0.139	0.000	0.000	0.134	0.000	0.253	51	3.480	0.000	7.516
MS201	LOWER DEAD ELK	SBW	6.426	6	0.712	0.098	0.349	0.173	0.035	0.000	0.089	0.000	0.291	39	2.125	0.000	4.779
MS176	MAPLE	SBW	6.523	5	0.252	0.042	0.652	0.105	0.197	0.000	0.123	0.866	0.000	43	4.135	0.000	5.844
MS186	MIDDLE	SBW	6.663	10	0.975	0.087	0.723	0.456	0.041	0.000	0.415	0.138	0.238	87	3.037	0.000	7.233
MS257	MILEPOST	SBW	6.574	5	0.496	0.116	0.320	0.289	0.003	0.000	0.081	0.000	0.255	30	2.608	0.000	7.721
MS237	MILLS	SBW	6.455	8	0.719	0.119	0.680	0.461	0.017	0.000	0.445	0.000	1.387	29	2.379	0.000	1.947
MS202	MUD	SBW	6.372	6	0.616	0.089	0.629	0.104	0.000	0.000	0.106	0.000	0.153	39	3.187	0.000	10.011
MS183	NELSON	SBW	6.665	9	0.931	0.132	0.683	0.242	0.036	0.000	0.143	0.000	0.482	82	5.384	0.000	12.614
MS155	NORTH COLT	SBW	6.713	6	0.677	0.049	0.574	0.153	0.017	0.000	0.103	0.000	0.247	52	3.414	0.000	4.528
MS253	NORTH KOOTENAI	SBW	6.352	5	0.442	0.068	0.362	0.127	0.000	0.000	0.098	0.000	0.713	18	2.382	0.000	0.000
MS149	PEARL	SBW	6.452	4	0.383	0.043	0.238	0.061	0.014	0.000	0.044	0.000	0.240	24	1.414	0.000	3.884
MS239	SHASTA	SBW	6.527	4	0.479	0.083	0.420	0.060	0.007	0.000	0.108	0.000	0.154	24	3.659	0.000	10.843
MS165	SIAH	SBW	7.148	26	3.114	0.601	0.552	0.303	0.013	0.000	0.079	0.000	0.549	238	4.593	0.000	18.475
MS156	SOUTH COLT	SBW	6.644	5	0.505	0.057	0.490	0.127	0.028	0.000	2.120	0.000	0.247	41	3.453	0.000	6.525
MS254	SOUTH KOOTENAI	SBW	6.415	5	0.547	0.078	0.322	0.089	0.000	0.000	0.123	0.000	0.324	22	1.922	0.000	21.191
MS194	UNKNOWN CANYON	SBW	6.621	11	1.110	0.124	0.642	0.441	0.041	0.000	0.533	0.000	0.376	76	2.546	0.000	11.484
MS200	UPPER DEAD ELK	SBW	6.340	6	0.616	0.079	0.397	0.173	0.029	0.000	0.156	0.000	0.291	34	2.109	0.000	5.340
MS255	UPPER MIDDLE FORK	SBW	6.518	7	0.855	0.109	0.342	0.183	0.016	0.000	0.165	0.000	0.949	30	2.326	0.000	14.933
MS174	WHITESAND	SBW	6.653	9	1.414	0.110	0.468	0.132	0.011	0.000	0.065	0.017	0.424	87	3.294	0.000	8.089
MS218	WIND 6790	SBW	6.509	7	0.814	0.087	0.677	0.176	0.000	0.000	0.209	0.000	0.199	57	2.276	0.000	4.337
MS219	WIND 7111	SBW	6.458	6	0.560	0.074	0.515	0.130	0.066	0.000	0.106	0.000	0.263	44	3.601	0.000	6.395

Appendix 2. 1992 Synoptic Water Chemistry from Anaconda-Pintlar, Cabinet Mountains, and Selway Bitterroot Wilderness Areas Displayed in ueq/L

FS ID#	LAKE	WA	CA	MG	NA	K	UEQ/L NH4	FL	CL	NO3	SO4	[ANC]	SUM ANIONS	SUM CATION	TOTAL ION	%ION DIFF	SUM BASES	SUM ACIDS	DIFF= ALK
MS210	BUCK	APW	15.67	13.33	24.10	13.96	4.05	0.00	7.05	0.00	26.42	12.40	45.87	72	118.26	-22.42	67.06	33.47	33.59
MS189	CARPP	APW	233.38	55.96	60.64	8.54	2.27	0.00	5.08	0.00	165.03	197.50	367.60	361	728.47	0.92	358.52	170.10	188.41
MS213	CRYSTAL	APW	73.35	22.63	84.12	12.20	0.00	0.00	6.60	0.00	6.06	127.50	140.16	192	332.57	-15.71	192.31	12.66	179.65
MS224	EDITH	APW	1075.15	132.40	32.62	48.42	1.55	0.00	6.46	0.00	51.32	1249.00	1306.78	1290	2596.93	0.64	1288.59	57.78	1230.81
MS153	FLOWER	APW	389.77	129.93	31.14	29.98	2.61	0.00	13.99	8.68	40.18	553.80	616.65	583	1200.10	2.77	580.82	62.85	517.97
MS223	HICKS	APW	166.92	34.97	34.84	4.50	0.00	0.00	5.98	0.00	23.59	214.40	243.97	241	485.29	0.55	241.23	29.57	211.66
MS246	HIDDEN	APW	1008.43	110.02	20.49	39.75	1.55	0.00	5.36	0.00	69.92	946.50	1021.78	1180	2202.02	-7.20	1178.68	75.28	1103.41
MS211	HOPE	APW	66.67	22.63	79.77	15.76	0.00	0.00	15.96	0.00	11.37	120.10	147.43	185	332.36	-11.28	184.83	27.33	157.49
MS161	IVANHOE	APW	83.43	43.20	11.05	9.90	1.77	0.00	4.26	4.39	17.34	112.50	138.49	150	288.08	-3.85	147.58	25.99	121.59
MS146	JOHNSON	APW	1460.58	233.86	21.66	44.04	5.43	0.00	2.82	0.00	34.83	1748.10	1785.75	1766	3551.34	0.57	1760.14	37.65	1722.49
MS245	KELLY	APW	652.69	145.98	28.14	19.82	2.16	0.00	9.45	0.00	4.79	760.20	774.44	849	1623.24	-4.58	846.64	14.24	832.40
MS227	LAMARCHE	APW	84.33	49.95	24.23	13.91	1.16	0.00	4.17	0.34	33.19	109.40	147.10	174	320.82	-8.30	172.42	37.70	134.72
MS214	LION	APW	109.88	28.80	100.91	20.49	0.00	0.00	11.06	0.00	16.91	185.20	213.16	260	473.31	-9.93	260.08	27.96	232.12
MS173	LITTLE JOHNSON	APW	850.30	327.59	24.84	25.42	1.83	0.00	16.59	0.44	7.93	1187.10	1212.05	1230	2442.03	-0.73	1228.15	24.95	1203.19
MS217	LITTLE RAINBOW	APW	257.19	29.87	15.70	8.06	0.00	0.00	3.78	0.00	48.16	264.90	316.84	311	627.69	0.95	310.82	51.94	258.88
MS228	LOST #1	APW	124.95	14.56	23.97	8.03	1.50	0.00	5.75	0.69	22.53	125.30	154.28	173	327.40	-5.76	171.51	28.98	142.54
MS229	LOST #2	APW	142.27	13.08	50.11	45.53	5.32	0.00	38.02	1.77	22.26	150.00	212.05	256	468.46	-9.47	250.98	62.05	188.93
MS190	LOWER CARPP	APW	221.51	54.06	61.51	11.66	3.10	0.00	6.01	0.00	153.95	205.50	365.46	352	717.39	1.89	348.74	159.96	188.78
MS147	MARTIN	APW	1125.75	159.31	16.49	37.62	3.44	0.00	4.12	0.00	30.25	1318.70	1353.07	1343	2695.68	0.39	1339.17	34.37	1304.80
MS212	MYSTIC	APW	69.36	17.44	64.68	5.09	0.00	0.00	2.99	0.00	7.83	115.60	126.42	157	283.08	-10.68	156.58	10.82	145.76
MS249	OREOMNOS	APW	860.43	113.97	17.09	20.69	1.55	0.00	6.80	0.00	13.80	889.00	909.60	1014	1923.35	-5.41	1012.18	20.60	991.58
MS152	PAGE	APW	963.57	179.80	19.49	26.91	1.61	0.00	5.70	0.00	52.80	1143.50	1202.00	1191	2393.38	0.44	1189.76	58.50	1131.27
MS171	PHYLLIS	APW	212.77	121.46	44.41	41.36	6.60	0.00	44.06	0.58	9.74	445.90	500.28	427	926.92	7.95	420.00	54.38	365.62
MS145	RAINBOW	APW	571.36	57.77	19.49	26.63	4.44	0.00	2.82	0.00	25.65	697.30	725.77	680	1405.46	3.28	675.24	28.47	646.76
MS244	RIPPLE	APW	621.41	128.37	32.88	19.39	1.55	0.00	9.00	0.00	36.56	686.00	731.56	804	1535.18	-4.69	802.05	45.56	756.49
MS247	SAWED CABIN	APW	731.69	93.23	20.49	27.62	1.55	0.00	6.80	0.00	19.61	771.50	797.91	875	1672.50	-4.58	873.03	26.41	846.62
MS208	SURPRISE	APW	219.61	11.27	34.84	3.91	4.44	0.00	3.84	0.00	7.39	236.00	247.23	274	521.35	-5.16	269.64	11.23	258.41
MS233	TAMARACK	APW	131.94	29.87	18.70	17.52	0.00	0.00	6.80	0.00	23.32	139.00	169.12	198	367.27	-7.91-	198.03	30.12	167.91
MS170	UNNAMED	APW	85.58	36.86	12.74	10.41	1.22	0.00	3.78	0.00	11.04	137.00	151.81	147	298.73	1.64	145.60	14.81	130.78
MS172	UNNAMED	APW	126.75	60.23	18.53	7.06	1.83	0.00	3.58	0.27	8.06	215.80	227.71	214	442.19	2.99	212.57	11.91	200.66
MS150	UNNAMED	APW	47.21	11.44	13.18	7.67	2.22	0.00	3.67	9.93	9.97	46.20	69.77	82	151.64	-7.97	79.50	23.57	55.92
MS191	UNNAMED T3NR15WS22	APW	139.42	36.78	63.03	26.50	5.54	0.00	15.68	1.94	118.53	133.60	269.75	271	541.16	-0.31	265.73	136.15	129.58
MS248	UNNAMED T2NR15WSE	APW	314.72	43.61	15.22	19.39	1.55	0.00	11.11	0.00	5.06	318.50	334.67	395	729.20	-8.21	392.94	16.17	376.77
MS234	UNNAMED T3NR15WSE	APW	145.86	46.33	52.28	18.72	4.05	0.00	9.00	0.00	56.42	156.10	221.52	267	488.86	-9.37	263.19	65.42	197.77
MS192	UNNAMED T3NR15WSE	APW	359.18	15.80	12.57	8.54	3.38	0.00	7.16	8.53	20.01	420.30	456.00	399	855.50	6.61	396.09	35.70	360.39
MS188	UPPER CARPP	APW	122.06	23.21	25.97	5.42	0.00	0.00	1.95	0.00	57.42	116.20	175.57	177	352.38	-0.35	176.65	59.37	117.28
MS151	UPPER SEYMOUR	APW	513.82	50.28	25.14	17.44	0.78	0.00	2.26	0.00	46.68	634.40	683.34	607	1290.81	5.88	606.68	48.94	557.75
MS209	VIOLET	APW	179.64	19.50	58.98	4.50	4.82	0.00	3.07	0.00	6.73	226.10	235.90	268	503.43	-6.28	262.63	9.80	252.83
MS263	WARREN	APW	128.84	23.62	24.62	6.29	0.67	0.00	4.54	0.00	21.51	124.00	150.05	184	334.16	-10.19	183.37	26.05	157.32
MS163	LAKE OF THE ISLE	near AP	235.53	56.78	57.42	21.28	0.94	0.00	4.12	0.24	128.07	163.40	295.83	372	667.99	-11.43	371.00	132.43	238.58
MS144	STORM LAKE	near AP	963.57	126.72	27.84	16.83	10.31	0.00	3.53	0.00	52.80	1067.00	1123.33	1145	2268.61	-0.97	1134.96	56.33	1078.64
MS175	UPPER FOURMILE BASI	near AP	108.33	24.52	19.01	9.31	1.00	0.00	3.75	0.00	23.30	145.10	172.15	162	334.41	2.96	161.17	27.05	134.12
MS262	UPPER NELSON	near AP	230.34	41.97	36.23	19.13	0.94	102.96	4.40	0.00	80.49	146.90	334.75	329	663.43	0.92	327.67	84.89	242.78
MS264	UPPER TENMILE	near AP	96.41	9.55	37.36	6.68	0.67	0.00	9.11	0.00	15.14	91.40	115.65	151	266.40	-13.18	149.99	24.25	125.75
MS162	UPPER TWIN	near AP	503.49	114.38	36.54	19.18	1.16	0.00	3.13	0.00	202.96	471.30	677.39	675	1352.19	0.19	673.59	206.09	467.50

Appendix 2. 1992 Synoptic Water Chemistry from Anaconda-Pintlar, Cabinet Mountains, and Selway Bitterroot Wilderness Areas
Displayed in ueq/L

FS ID#	LAKE	WA	CA	MG	NA	K	UEQ/L NH4	FL	CL	NO3	SO4	[ANC]	SUM ANIONS	SUM CATION	TOTAL ION	%ION DIFF	SUM BASES	SUM ACIDS	DIFF= ALK	ANC
MS199	BAREE	CMW	34.68	15.80	23.75	3.07	2.00	0.00	3.55	0.00	18.45	51.40	73.40	80	152.90	-3.99	77.30	22.00	55.30	51.40
MS230	DOUBLE	CMW	159.78	38.68	20.53	6.34	1.50	0.00	2.28	0.00	19.07	144.80	166.16	227	393.09	-15.46	225.33	21.36	203.97	144.80
MS260	ENGLE	CMW	37.33	10.29	18.36	4.83	0.00	0.00	7.70	0.42	7.91	35.70	51.73	71	122.81	-15.75	70.80	16.03	54.77	35.70
MS182	GRANITE	CMW	234.83	152.64	7.74	3.86	1.22	0.00	2.03	3.08	27.75	404.60	437.47	400	837.80	4.43	399.08	32.87	366.21	404.60
MS206	LEIGH	CMW	65.02	33.16	9.09	2.66	2.27	0.00	4.37	0.00	8.87	85.20	98.44	112	210.78	-6.59	109.93	13.24	96.69	85.20
MS197	LOWER BRAML	CMW	12.57	5.92	16.09	2.30	1.50	0.00	3.27	0.00	6.29	24.00	33.56	39	72.40	-7.29	36.90	9.56	27.34	24.00
MS159	LOWER LIBBY	CMW	12.38	5.02	7.53	1.51	0.55	0.00	1.16	0.00	5.14	17.00	23.30	27	50.70	-8.10	26.43	6.30	20.13	17.00
MS215	LOWER SKY	CMW	199.55	75.21	22.10	12.20	0.00	0.00	4.60	0.00	19.99	257.20	281.79	309	590.87	-4.62	309.06	24.59	284.47	257.20
MS205	MINOR	CMW	339.82	105.99	24.71	11.56	1.94	0.00	5.27	0.00	42.22	519.50	567.00	484	1051.04	7.89	482.07	47.50	434.57	519.50
MS259	MORAN BASIN	CMW	165.52	95.54	13.70	7.39	2.44	0.00	5.36	0.00	0.00	216.50	221.86	285	506.54	-12.40	282.15	5.36	276.79	216.50
MS258	ROCK	CMW	55.79	26.50	13.92	3.73	0.00	0.00	5.95	0.00	5.89	59.50	71.34	100	171.42	-16.76	99.94	11.84	88.09	59.50
MS198	UPPER BRAML	CMW	19.81	5.92	14.79	2.69	1.22	0.00	3.27	0.00	7.83	26.90	38.00	45	82.82	-8.23	43.21	11.10	32.11	26.90
MS207	UPPER CEDAR	CMW	108.48	99.98	11.70	5.68	2.16	0.00	5.16	0.00	13.68	162.00	180.84	228	408.95	-11.56	225.84	18.84	207.00	162.00
MS180	UPPER GEIGER	CMW	29.54	7.16	16.75	3.07	1.22	0.00	4.03	0.00	7.16	51.30	62.50	58	120.57	3.67	56.52	11.20	45.32	51.30
MS157	UPPER LIBBY	CMW	4.54	0.99	6.18	1.51	1.55	0.00	2.14	0.00	4.56	6.10	12.80	16	28.61	-10.50	13.21	6.70	6.51	6.10
MS216	UPPER SKY	CMW	431.79	172.23	10.66	22.28	2.55	0.00	4.80	0.00	12.51	626.80	644.11	640	1283.62	0.36	636.95	17.31	619.64	626.80
MS231	UPPER VIMY	CMW	200.15	37.93	111.92	26.14	5.65	0.00	84.20	0.00	32.67	181.20	298.06	382	679.98	-12.33	376.14	116.86	259.28	181.20
MS221	BIG CREEK	SBW	39.32	7.16	16.05	8.64	3.33	0.00	7.14	0.00	9.47	40.50	57.11	75	132.02	-13.49	71.18	16.61	54.57	40.50
MS148	BIG CREEK	SBW	29.09	11.44	13.53	2.17	1.39	0.00	1.52	0.69	8.06	28.20	38.47	58	96.40	-20.18	56.23	10.27	45.96	28.20
MS256	BIG GRIZZLY	SBW	24.75	8.15	16.36	9.23	0.17	0.00	5.47	0.00	5.31	33.40	44.18	59	103.10	-14.30	58.49	10.78	47.70	33.40
MS169	BILL'S	SBW	24.85	3.62	13.88	1.53	1.00	0.00	1.44	0.58	6.37	35.50	43.89	45	89.00	-1.37	43.88	8.39	35.49	35.50
MS167	BLODGETT	SBW	9.13	2.14	8.35	1.30	2.44	0.00	3.19	0.00	4.96	17.70	25.84	24	50.18	3.01	20.93	8.14	12.78	17.70
MS195	BOULDER	SBW	61.13	6.50	31.45	15.58	2.27	0.00	19.41	0.00	12.70	77.60	109.71	117	226.87	-3.29	114.65	32.11	82.55	77.60
MS251	BUCK	SBW	54.79	16.38	46.28	4.22	0.00	0.00	3.16	0.00	2.69	83.50	89.35	122	211.17	-15.38	121.67	5.85	115.82	83.50
MS220	CANYON	SBW	43.16	6.09	32.49	13.96	16.58	0.00	17.01	0.00	7.97	46.70	71.68	113	184.38	-22.25	95.71	24.98	70.73	46.70
MS236	CARLTON	SBW	14.47	9.79	29.80	5.50	0.94	0.00	5.13	0.00	28.09	20.50	53.72	61	114.59	-6.24	59.56	33.22	26.34	20.50
MS193	CRYSTAL	SBW	126.05	10.86	34.97	11.66	2.27	0.00	8.10	0.00	19.34	160.10	187.54	186	373.45	0.44	183.54	27.44	156.11	160.10
MS196	EAGLE MTN.	SBW	19.81	4.03	14.35	2.30	1.22	0.00	2.43	0.00	2.52	39.00	43.95	42	85.86	2.37	40.50	4.95	35.55	39.00
MS168	EMERALD	SBW	29.99	3.62	14.53	1.84	0.39	0.00	1.81	0.58	6.37	34.90	43.66	51	94.25	-7.36	49.98	8.76	41.22	34.90
MS225	FISH LAKE	SBW	33.13	8.56	20.01	2.97	1.50	0.00	2.37	0.00	5.46	40.20	48.02	66	114.45	-16.07	64.67	7.82	56.84	40.20
MS242	FRED BURR	SBW	39.97	6.83	31.27	10.23	2.33	0.00	17.40	0.00	6.39	38.80	62.60	91	153.49	-18.44	88.31	23.80	64.51	38.80
MS185	GEM LAKE	SBW	50.90	6.50	21.57	5.81	1.77	0.00	4.20	3.08	4.29	80.00	91.57	87	178.32	2.70	84.78	11.57	73.21	80.00
MS240	HEINRICH	SBW	30.79	4.53	31.06	9.44	0.94	0.00	19.94	0.00	1.62	28.30	49.87	77	126.93	-21.43	75.81	21.57	54.24	28.30
MS238	HOLLOWAY	SBW	43.06	12.84	15.79	7.47	0.39	0.00	2.93	0.00	37.10	24.60	64.64	80	144.51	-10.55	79.16	40.04	39.12	24.60
MS178	KETTLE	SBW	23.60	4.03	9.09	3.07	0.00	0.00	3.75	2.52	3.85	35.10	45.22	40	85.49	5.79	39.80	10.12	29.68	35.10
MS235	LITTLE CARLT	SBW	21.96	9.79	52.41	11.02	1.77	0.00	19.52	0.00	25.44	30.00	74.96	97	172.35	-13.01	95.19	44.96	50.22	30.00
MS243	LITTLE GRIZZL	SBW	26.85	8.31	14.31	7.06	0.39	0.00	3.92	0.00	6.12	28.30	38.34	57	95.51	-19.71	56.53	10.04	46.49	28.30
MS241	LOCKWOOD	SBW	34.83	6.83	21.23	6.68	2.88	0.00	10.01	0.00	4.54	38.10	52.65	73	125.39	-16.02	69.56	14.55	55.01	38.10
MS203	LOTTIE #1	SBW	35.53	6.50	26.84	2.66	1.28	0.00	1.75	0.00	2.52	45.20	49.47	73	122.58	-19.29	71.53	4.27	67.26	45.20
MS204	LOTTIE #2	SBW	37.92	7.32	32.41	3.56	0.00	0.00	3.78	0.00	5.27	50.90	59.95	82	141.46	-15.25	81.21	9.05	72.16	50.90
MS201	LOWER DEAD	SBW	35.53	8.06	15.18	4.42	1.94	0.00	2.51	0.00	6.06	39.30	47.87	66	113.38	-15.56	63.20	8.57	54.63	39.30
MS176	MAPLE	SBW	12.57	3.46	28.36	2.69	10.92	0.00	3.47	13.97	0.00	43.30	60.74	58	119.03	2.05	47.08	17.44	29.64	43.30
MS186	MIDDLE	SBW	48.65	7.16	31.45	11.66	2.27	0.00	11.71	2.23	4.96	87.30	106.19	101	207.60	2.30	98.92	18.89	80.04	87.30
MS257	MILEPOST	SBW	24.75	9.55	13.92	7.39	0.17	0.00	2.28	0.00	5.31	30.10	37.69	56	93.73	-19.57	55.61	7.59	48.01	30.10
MS237	MILLS	SBW	35.88	9.79	29.58	11.79	0.94	0.00	12.55	0.00	28.88	28.60	70.03	88	158.36	-11.56	87.04	41.43	45.61	28.60
MS202	MUD	SBW	30.74	7.32	27.36	2.66	0.00	0.00	2.99	0.00	3.19	38.60	44.78	69	113.28	-20.95	68.08	6.18	61.91	38.60
MS183	NELSON	SBW	46.46	10.86	29.71	6.19	2.00	0.00	4.03	0.00	10.04	81.80	95.87	95	191.30	0.23	93.22	14.07	79.15	81.80
MS155	NORTH COLT	SBW	33.78	4.03	24.97	3.91	0.94	0.00	2.91	0.00	5.14	51.90	59.95	68	127.78	-6.17	66.70	8.05	58.65	51.90
MS253	NORTH KOOTE	SBW	22.06	5.60	15.75	3.25	0.00	0.00	2.76	0.00	14.85	18.30	35.91	47	83.00	-13.47	46.65	17.61	29.04	18.30
MS149	PEARL	SBW	19.11	3.54	10.35	1.56	0.78	0.00	1.24	0.00	5.00	23.80	30.04	36	65.73	-8.60	34.56	6.24	28.32	23.80
MS239	SHASTA	SBW	23.90	6.83	18.27	1.53	0.39	0.00	3.05	0.00	3.21	24.00	30.25	51	81.47	-25.74	50.54	6.25	44.28	24.00
MS165	SIAH	SBW	155.39	49.45	24.01	7.75	0.72	0.00	2.23	0.00	11.43	237.90	251.56	237	488.96	2.90	236.60	13.66	222.95	237.90
MS156	SOUTH COLT	SBW	25.20	4.69	21.31	3.25	1.55	0.00	59.80	0.00	5.14	40.90	105.84	56	162.07	30.61	54.45	64.94	-10.49	40.90
MS254	SOUTH KOOTE	SBW	27.30	6.42	14.01	2.28	0.00	0.00	3.47	0.00	6.75	22.40	32.62	50	83.00	-21.41	50.00	10.22	39.78	22.40
MS194	UNKNOWN CA	SBW	55.39	10.20	27.93	11.28	2.27	0.00	15.03	0.00	7.83	76.40	99.26	107	206.57	-3.90	104.80	22.86	81.93	76.40
MS200	UPPER DEAD E	SBW	30.74	6.50	17.27	4.42	1.61	0.00	4.40	0.00	6.06	34.20	44.66	61	105.66	-15.46	58.93	10.46	48.47	34.20
MS255	UPPER MIDDLE	SBW	42.66	8.97	14.88	4.68	0.89	0.00	4.65	0.00	19.76	29.60	54.01	72	126.39	-14.53	71.19	24.41	46.78	29.60
MS174	WHITESAND	SBW	70.56	9.05	20.36	3.38	0.61	0.00	1.83	0.27	8.83	86.90	97.84	104	202.01	-3.14	103.34	10.94	92.41	86.90
MS218	WIND 6790	SBW	40.62	7.16	29.45	4.50	0.00	0.00	5.90	0.00	4.14	57.30	67.34	82	149.38	-9.84	81.73	10.04	71.69	57.30
MS219	WIND 7111	SBW	27.94	6.09	22.40	3.32	3.66	0.00	2.99	0.00	5.48	44.00	52.47	64	116.23	-9.72	59.76	8.47	51.29	44.00

Appendix 3. Comparison of Lakes Sampled both in the WLS (1985) and R1 (1992) Lake Surveys

Area	Lake		pH	ANC ueq/l	Ca ueq/l	Mg ueq/l	Na ueq/l	K ueq/l	NH4 ueq/l	SO4 ueq/l	Cl ueq/l	NO3 ueq/l	F ueq/l	Cond. uS/cm
APW	Hope	WLS	7.28	119.4	64.2	19	58.4	7.7	0	17.5	4	0.7	1.1	14
		R1	7.01	120.1	66.7	22.6	78.8	15.8	0	11.4	16	0	0	15.4
APW	Rainbow	WLS	8.26	588.4	514.5	50.5	18.1	23.7	0	31.5	2.7	5.8	0.9	60.4
		R1	7.82	697.3	571.4	57.8	19.5	26.7	4.4	25.7	2.8	0	0	58.9
CMW	Lower Sky	WLS	7.48	261.1	196.8	68.8	18.1	10.9	0	21.7	3	0.1	0.8	27.8
		R1	7.5	257.2	199.6	75.2	22.1	12.2	0	20	4.6	0	0	30.1
SBW	Holloway	WLS	6.66	29.0	34.0	10.8	12.3	6.2	0.0	36.2	1.6	0.3	0.5	8.9
		R1	6.48	24.6	43.1	12.8	15.8	7.5	0.4	37.1	2.9	0	0	7.6
SBW	Lt Carltn	WLS	6.45	19.0	20.6	8.0	24.1	5.0	0.0	26.0	4.9	0.3	0.4	5.5
		R1	6.43	20.5	14.5	9.8	29.8	5.5	0.9	28.9	5.1	0	0	6.5
SBW	Heinrich	WLS	6.98	29.5	22.3	3.9	8.3	14.3	0.0	3.9	2.8	0.9	0.4	3.8
		R1	6.5	28.3	30.1	4.5	31.1	9.5	0.9	1.6	19.9	0.9	0	6.7
SBW	Blodgett	WLS	6.95	21.3	13.6	2.9	8.1	1.6	0.0	5.3	1.6	0.8	0.4	3.3
		R1	6.01	17.7	9.1	2.1	8.4	1.3	2.4	4.9	3.2	0	0	3.3
SBW	Fish	WLS	6.39	47.2	29.2	5.5	21.0	2.4	0.0	5.6	1.3	0.0	0.3	5.8
		R1	6.59	40.2	33.1	8.6	20	3	1.5	5.5	2.4	0	0	5.4
SBW	Milepost	WLS	6.78	38.8	25.4	8.0	11.4	6.3	0.0	7.9	1.6	0.3	0.5	4.7
		R1	6.57	30.1	24.8	9.6	13.9	7.4	0.2	5.3	0	0	0	5.1
SBW	Colt	WLS	6.86	50.3	32.6	5.4	20.7	2.9	0.0	5.7	2.1	1.4	0.4	7.1
		R1	6.71	51.9	33.8	4	25	3.9	0	5.1	2.9	0	0	5.8
SBW	EaglMtn	WLS	6.89	42.9	27.2	5.2	13.5	2.3	0.0	3.5	1.9	0.4	0.5	4.5
		R1	6.71	39	19.8	4	14.4	2.3	0	1.2	2.5	0	0	4.7
SBW	Buck	WLS	7.12	107.0	54.4	15.5	47.8	5.2	0.0	3.2	2.2	2.3	2.5	10.7
		R1	6.81	83.5	54.8	16.4	46.3	4.2	0	2.7	3.1	0	0	9.6

Appendix 4. 1992 Synoptic Water Chemistry from AP, CM, and SBW

Sorted by ANC

FS ID#	LAKE	WILDERNESS AREA	lab pH	uS/cm Conduct.	Ca	Mg	Na	K	NH4	P	Cl	NO3	SO4	UEQ/L ANC	MG/L SiO2
					MG/L										
MS157	UPPER LIBBY LAKE	CABINET MTS	5.983	1.954	0.091	0.012	0.142	0.059	0.028	0.000	0.076	0.000	0.219	6.100	0.948
MS210	BUCK LAKE	ANACONDA-PI	5.893	7.924	0.314	0.162	0.354	0.546	0.073	0.000	0.250	0.000	1.269	12.400	0.355
MS159	LOWER LIBBY LAKE	CABINET MTS	6.375	3.040	0.248	0.061	0.173	0.059	0.010	0.000	0.041	0.000	0.247	17.000	1.483
MS167	BLODGETT LAKE	SELWAY-BITTE	6.015	3.310	0.183	0.026	0.192	0.051	0.044	0.000	0.113	0.000	0.238	17.700	1.656
MS253	NORTH KOOTENAI LA	SELWAY-BITTE	6.352	5.131	0.442	0.068	0.362	0.127	0.000	0.000	0.098	0.000	0.713	18.300	2.382
MS236	CARLTON LAKE	SELWAY-BITTE	6.434	6.567	0.290	0.119	0.685	0.215	0.017	0.000	0.182	0.000	1.349	20.500	3.567
MS254	SOUTH KOOTENAI LA	SELWAY-BITTE	6.415	5.237	0.547	0.078	0.322	0.089	0.000	0.000	0.123	0.000	0.324	22.400	1.922
MS149	PEARL LAKE	SELWAY-BITTE	6.452	3.734	0.383	0.043	0.238	0.061	0.014	0.000	0.044	0.000	0.240	23.800	1.414
MS259	SHASTA LAKE	SELWAY-BITTE	6.527	4.392	0.479	0.083	0.420	0.060	0.007	0.000	0.108	0.000	0.154	24.000	3.659
MS197	LOWER BRAMLET	CABINET MTS	6.349	4.612	0.252	0.072	0.370	0.090	0.027	0.000	0.116	0.000	0.302	24.000	3.149
MS238	HOLLOWAY LAKE	SELWAY-BITTE	6.481	7.378	0.863	0.156	0.363	0.292	0.007	0.000	0.104	0.000	1.782	24.600	2.107
MS198	UPPER BRAMLET	CABINET MTS	6.411	4.897	0.397	0.072	0.340	0.105	0.022	0.000	0.116	0.000	0.376	26.900	2.698
MS148	BIG CREEK LAKE	SELWAY-BITTE	6.513	4.603	0.583	0.139	0.311	0.085	0.025	0.000	0.054	0.043	0.387	28.200	2.060
MS243	LITTLE GRIZZLY LAK	SELWAY-BITTE	6.602	5.028	0.538	0.101	0.329	0.276	0.007	0.000	0.139	0.000	0.294	28.300	2.182
MS240	HEINRICH LAKE	SELWAY-BITTE	6.500	6.725	0.617	0.055	0.714	0.369	0.017	0.000	0.707	0.000	0.078	28.300	1.362
MS257	MILLS LAKE	SELWAY-BITTE	6.455	8.423	0.719	0.119	0.680	0.461	0.017	0.000	0.445	0.000	1.387	28.600	2.379
MS255	UPPER MIDDLE FORK	SELWAY-BITTE	6.518	6.972	0.855	0.109	0.542	0.183	0.016	0.000	0.165	0.000	0.949	29.600	2.326
MS235	LITTLE CARLTON LA	SELWAY-BITTE	6.373	8.990	0.440	0.119	1.205	0.431	0.032	0.000	0.692	0.000	1.222	30.000	4.152
MS257	MILEPOST LAKE	SELWAY-BITTE	6.574	5.103	0.496	0.116	0.320	0.289	0.003	0.000	0.081	0.000	0.255	30.100	2.608
MS256	BIG GRIZZLY LAKE	SELWAY-BITTE	6.570	5.869	0.496	0.099	0.376	0.361	0.003	0.000	0.194	0.000	0.255	33.400	2.484
MS200	UPPER DEAD ELK LA	SELWAY-BITTE	6.340	5.609	0.616	0.079	0.397	0.173	0.029	0.000	0.156	0.000	0.291	34.200	2.109
MS168	EMERALD LAKE	SELWAY-BITTE	6.653	4.990	0.601	0.044	0.334	0.072	0.007	0.000	0.064	0.036	0.306	34.900	2.387
MS178	KETTLE LAKE	SELWAY-BITTE	6.321	4.938	0.473	0.049	0.209	0.120	0.000	0.000	0.133	0.156	0.185	35.100	1.172
MS169	BILL'S LAKE	SELWAY-BITTE	6.643	4.897	0.498	0.044	0.319	0.060	0.018	0.000	0.051	0.036	0.306	35.500	2.742
MS260	ENGLE LAKE	CABINET MTS	6.358	6.244	0.748	0.125	0.422	0.189	0.000	0.000	0.273	0.026	0.380	35.700	3.611
MS241	LOCKWOOD LAKE	SELWAY-BITTE	6.328	6.402	0.698	0.083	0.488	0.261	0.052	0.000	0.355	0.000	0.218	38.100	2.402
MS202	MUD LAKE	SELWAY-BITTE	6.372	5.536	0.616	0.089	0.629	0.104	0.000	0.000	0.106	0.000	0.153	38.600	3.187
MS242	FRED BURR LAKE	SELWAY-BITTE	6.590	7.932	0.801	0.083	0.719	0.400	0.042	0.000	0.617	0.000	0.307	38.800	1.545
MS196	EAGLE MTN. LAKE	SELWAY-BITTE	6.712	4.734	0.397	0.049	0.330	0.090	0.022	0.000	0.086	0.000	0.121	39.000	3.227
MS201	LOWER DEAD ELK LA	SELWAY-BITTE	6.426	5.567	0.712	0.098	0.549	0.173	0.035	0.000	0.089	0.000	0.291	39.300	2.125
MS225	FISH LAKE	SELWAY-BITTE	6.591	5.372	0.664	0.104	0.460	0.116	0.027	0.000	0.084	0.000	0.262	40.200	2.054
MS221	BIG CREEK LAKE	SELWAY-BITTE	6.384	6.927	0.788	0.087	0.369	0.338	0.060	0.000	0.253	0.000	0.455	40.500	2.532
MS156	SOUTH COLT LAKE	SELWAY-BITTE	6.644	5.122	0.505	0.057	0.490	0.127	0.028	0.000	2.120	0.000	0.247	40.900	3.453
MS176	MAPLE LAKE	SELWAY-BITTE	6.523	5.103	0.252	0.042	0.652	0.105	0.197	0.000	0.123	0.866	0.000	43.300	4.135
MS219	WIND 7111 LAKE	SELWAY-BITTE	6.458	5.883	0.560	0.074	0.315	0.130	0.066	0.000	0.106	0.000	0.263	44.000	3.601
MS203	LOTTIE #1	SELWAY-BITTE	6.504	5.701	0.712	0.079	0.617	0.104	0.023	0.000	0.062	0.000	0.121	45.200	2.576
MS150	UNNAMED LAKE	ANACONDA-PI	6.815	6.341	0.946	0.139	0.303	0.300	0.040	0.000	0.130	0.616	0.479	46.200	2.440
MS220	CANYON LAKE	SELWAY-BITTE	6.384	9.074	0.865	0.074	0.747	0.546	0.299	0.000	0.603	0.000	0.383	46.700	2.247
MS204	LOTTIE #2	SELWAY-BITTE	6.514	6.526	0.760	0.089	0.745	0.139	0.000	0.000	0.134	0.000	0.253	50.900	3.480
MS180	UPPER GEIGER	CABINET MTS	6.473	6.351	0.592	0.087	0.385	0.120	0.022	0.000	0.143	0.000	0.344	51.300	2.890
MS199	BAREE LAKE	CABINET MTS	6.686	8.337	0.695	0.192	0.546	0.120	0.036	0.000	0.126	0.000	0.886	51.400	3.090
MS155	NORTH COLT LAKE	SELWAY-BITTE	6.713	5.809	0.677	0.049	0.374	0.153	0.017	0.000	0.103	0.000	0.247	51.900	3.414
MS218	WIND 6790 LAKE	SELWAY-BITTE	6.509	7.388	0.814	0.087	0.677	0.176	0.000	0.000	0.209	0.000	0.199	57.300	2.276
MS258	ROCK LAKE	CABINET MTS	6.846	7.653	1.118	0.322	0.320	0.146	0.000	0.000	0.211	0.000	0.283	59.500	1.211
MS194	UNKNOWN CANYON L	SELWAY-BITTE	6.621	10.577	1.110	0.124	0.642	0.441	0.041	0.000	0.533	0.000	0.376	76.400	2.546
MS195	BOULDER LAKE	SELWAY-BITTE	6.622	11.666	1.225	0.079	0.723	0.609	0.041	0.000	0.688	0.000	0.610	77.600	2.464
MS185	GEM LAKE	SELWAY-BITTE	6.706	8.733	1.020	0.079	0.496	0.227	0.032	0.000	0.149	0.191	0.206	80.000	2.895
MS183	NELSON LAKE	SELWAY-BITTE	6.665	9.392	0.931	0.132	0.683	0.242	0.036	0.000	0.143	0.000	0.482	81.800	5.384
MS251	BUCK LAKE	SELWAY-BITTE	6.810	9.628	1.098	0.199	1.064	0.165	0.000	0.000	0.112	0.000	0.129	83.500	2.784
MS206	LEIGH LAKE	CABINET MTS	6.872	9.496	1.303	0.403	0.209	0.104	0.041	0.000	0.155	0.000	0.426	85.200	1.220
MS174	WHITESAND LAKE	SELWAY-BITTE	6.653	8.880	1.414	0.110	0.468	0.132	0.011	0.000	0.065	0.017	0.424	86.900	3.294
MS186	MIDDLE LAKE	SELWAY-BITTE	6.663	10.465	0.975	0.087	0.723	0.456	0.041	0.000	0.415	0.138	0.238	87.300	3.037
MS264	UPPER TENMILE	OUTSIDE AP	7.041	11.891	1.932	0.116	0.859	0.261	0.012	0.000	0.323	0.000	0.727	91.400	2.609
MS227	LAMARCHE LAKE	ANACONDA-PI	6.868	14.032	1.690	0.607	0.557	0.544	0.021	0.000	0.148	0.021	1.594	109.400	3.946
MS161	IVANHOE LAKE	ANACONDA-PI	6.621	12.536	1.672	0.325	0.254	0.387	0.032	0.000	0.151	0.272	0.833	112.500	3.382
MS212	MYSTIC LAKE	ANACONDA-PI	7.057	12.824	1.390	0.212	1.487	0.199	0.000	0.000	0.106	0.000	0.376	115.600	5.856
MS188	UPPER CARPP LAKE	ANACONDA-PI	6.810	17.245	2.446	0.282	0.597	0.212	0.000	0.000	0.069	0.000	2.758	116.200	3.633
MS211	HOPE LAKE	ANACONDA-PI	7.011	15.436	1.336	0.275	1.834	0.616	0.000	0.000	0.566	0.000	0.546	120.100	6.464
MS263	WARREN LAKE	ANACONDA-PI	7.097	14.482	2.582	0.287	0.566	0.246	0.012	0.000	0.161	0.000	1.033	124.000	2.748
MS228	LOST LAKE #1	ANACONDA-PI	6.937	14.145	2.504	0.177	0.551	0.314	0.027	0.000	0.204	0.043	1.082	125.300	1.319
MS213	CRYSTAL LAKE	ANACONDA-PI	6.963	15.404	1.470	0.275	1.934	0.477	0.000	0.000	0.234	0.000	0.291	127.500	4.565
MS191	UNNAMED LAKE T3N	ANACONDA-PI	6.876	32.780	2.794	0.447	1.449	1.036	0.100	0.000	0.356	0.120	5.693	133.600	5.698
MS170	UNNAMED LAKE	ANACONDA-PI	7.030	13.351	1.715	0.448	0.293	0.407	0.022	0.000	0.134	0.000	0.530	137.000	2.816
MS253	TAMARACK LAKE	ANACONDA-PI	6.914	16.918	2.644	0.363	0.430	0.685	0.000	0.000	0.241	0.000	1.120	139.000	1.985
MS230	DOUBLE LAKE	CABINET MTS	6.967	10.840	3.202	0.470	0.472	0.248	0.027	0.000	0.081	0.000	0.916	144.800	1.386
MS175	UPPER FOURMILE BA	OUTSIDE AP	7.051	15.545	2.171	0.298	0.437	0.364	0.018	0.000	0.133	0.000	1.119	145.100	2.297
MS262	UPPER NELSON	OUTSIDE AP	7.181	33.062	4.616	0.310	0.833	0.748	0.017	1.956	0.156	0.000	3.866	146.900	4.134
MS229	LOST LAKE #2	ANACONDA-PI	7.015	26.291	2.851	0.159	1.152	1.780	0.096	0.000	1.348	0.110	1.069	150.000	0.670
MS234	UNNAMED T3NR15WS	ANACONDA-PI	6.999	27.718	2.923	0.563	1.202	0.732	0.073	0.000	0.319	0.000	2.710	156.100	5.325
MS193	CRYSTAL LAKE	SELWAY-BITTE	7.031	17.846	2.526	0.132	0.804	0.456	0.041	0.000	0.287	0.000	0.929	160.100	3.666
MS207	UPPER CEDAR LAKE	CABINET MTS	6.969	16.805	2.174	1.215	0.269	0.222	0.039	0.000	0.183	0.000	0.657	162.000	2.141
MS163	LAKE OF THE ISLE	OUTSIDE AP	6.668	36.414	4.720	0.690	1.320	0.832	0.017	0.000	0.146	0.015	6.151	163.400	9.256
MS231	UPPER VIMY LAKE	CABINET MTS	6.929	39.140	4.011	0.461	2.573	1.022	0.102	0.000	2.985	0.000	1.569	181.200	1.503
MS214	LION LAKE	ANACONDA-PI	7.159	21.095	2.202	0.350	2.520	0.801	0.000	0.000	0.392	0.000	0.812	185.200	8.044
MS189	CARPP LAKE	ANACONDA-PI	7.089	41.433	4.677	0.680	1.394	0.334	0.041	0.000	0.180	0.000	7.926	197.500	8.593
MS190	LOWER CARPP LAKE	ANACONDA-PI	7.062	40.618	4.439	0.657	1.414	0.456	0.056	0.000	0.213	0.000	7.394	205.500	6.841
MS223	HICKS LAKE	ANACONDA-PI	7.060	26.330	3.345	0.425	0.801	0.176	0.000	0.000	0.212	0.000	1.133	214.400	3.693
MS172	UNNAMED LAKE	ANACONDA-PI	7.142	19.558	2.540	0.732	0.426	0.276	0.033	0.000	0.127	0.017	0.387	215.800	2.437
MS259	MORAN BASIN	CABINET MTS	7.040	21.322	3.317	1.161	0.315	0.289	0.044	0.000	0.190	0.000	0.000	216.500	0.418
MS209	VIOLET LAKE	ANACONDA-PI	7.109	26.992	3.600	0.237	1.356	0.176	0.087	0.000	0.109	0.000	0.323	226.100	2.693
MS208	SURPRISE LAKE	ANACONDA-PI	7.283	27.642	4.401	0.137	0.801	0.153	0.080	0.000	0.136	0.000	0.355	236.000	3.970
MS165	SIAH LAKE	SELWAY-BITTE	7.148	26.010	3.114	0.601	0.352	0.303	0.013	0.000	0.079	0.000	0.549	237.900	4.593
MS215	LOWER SKY LAKE	CABINET MTS	7.335	30.153	3.999	0.914	0.508	0.477	0.000	0.000	0.163	0.000	0.960	257.200	3.407
MS217	LITTLE RAINBOW LAK	ANACONDA-PI	7.468	33.856	5.154	0.363	0.361	0.315	0.000	0.000	0.134	0.000	2.313	264.900	1.110
MS248	UNNAMED T2NR15WS	ANACONDA-PI	7.355	37.788	6.307	0.330	0.350	0.758	0.028	0.000	0.394	0.000	0.243	318.500	0.118
MS182	GRANITE LAKE	CABINET MTS	7.399	39.900	4.706	1.855	0.178	0.151	0.022	0.000	0.072	0.191	1.333	404.600	1.289
MS192	UNNAMED T3NR15WS	ANACONDA-PI	7.737	44.487	7.198	0.192	0.289	0.334	0.061	0.000	0.254	0.329	0.961	420.300	1.232
MS171	PHYLLIS LAKE	ANACONDA-PI	7.378	47.735	4.264	1.476	1.021	1.617	0.119	0.000	1.562	0.036	0.468	445.900	2.264
MS162	UPPER TWIN	OUTSIDE AP	7.447	63.852	10.090	1.390	0.840	0.750	0.021	0.000	0.111	0.000	9.748	471.300	7.315
MS205	MINOR LAKE	CABINET MTS	7.649	54.024	6.810	1.288	0.568	0.452	0.035	0.000	0.187	0.000	2.028	519.500	2.823
MS153	FLOWER LAKE	ANACONDA-PI	7.690	55.045	7.811	1.579	0.716	1.172	0.047	0.000	0.496	0.338	1.930	553.800	3.326
MS216	UPPER SKY LAKE	CABINET MTS	7.959	59.248	8.653	2.093	0.245	0.871	0.046	0.000	0.170	0.000	0.601	626.800	4.362
MS151	UPPER SEYMOUR LAK	ANACONDA-PI	7.942	58.693	10.297	0.611	0.378	0.682	0.014	0.000	0.080	0.000	2.242	634.400	4.461
MS244	RIPPLE LAKE	ANACONDA-PI	7.768	71.204	12.453	1.560	0.756	0.758	0.028	0.000	0.319	0.000	1.756	686.000	6.187
MS145	RAINBOW LAKE	ANACONDA-PI	7.821	58.870	11.450	0.702	0.448	1.041	0.080	0.000	0.100	0.000	1.232	697.500	3.046
MS245	KELLY LAKE	ANACONDA-PI	8.788	74.744	13.080	1.774	0.647	0.775	0.039	0.000	0.335	0.000	0.230	760.200	4.364
MS247	SAWED CABIN LAKE	ANACONDA-PI	8.055	78.387	14.663	1.133	0.471	1.080	0.028	0.000	0.241	0.000	0.942	771.500	3.833
MS249	OREOMNOS LAKE	ANACONDA-PI	8.038	88.589	17.243	1.385	0.393	0.809	0.028	0.000	0.241	0.000	0.663	889.000	1.929
MS246	HIDDEN LAKE	ANACONDA-PI	8.258	96.917	20.209	1.337	0.471	1.354	0.028	0.000	0.190	0.000	3.358	946.500	2.101
MS144	STORM LAKE	OUTSIDE AP	7.927	95.161	19.310	1.540	0.640	0.658	0.186	0.000	0.125	0.000	2.536	1067.000	4.403
MS152	PAGE LAKE	ANACONDA-PI	8.414	96.892	19.310	2.185	0.448	1.052	0.029	0.000	0.202	0.000	2.536	1143.500	1.888
MS173	LITTLE JOHNSON LAK	ANACONDA-PI	8.848	98.667	17.040	3.981	0.371	0.994	0.033	0.000	0.588	0.027	0.381	1187.100	0.633
MS224	EDITH LAKE	ANACONDA-PI	8.146	108.152	21.546	1.609	0.750	1.893	0.028	0.000	0.229	0.000	2.465	1249.000	5.106
MS147	MARTIN LAKE	ANACONDA-PI	8.160	109.389	22.560	1.936	0.379	1.471	0.062	0.000	0.146	0.000	1.453	1318.700	2.494
MS146	JOHNSON LAKE	ANACONDA-PI	8.234	140.319	29.270	2.842	0.498	1.722	0.098	0.000	0.100	0.000	1.673	1748.100	3.548

Appendix 5. 1992 Synoptic Water Chemistry from APW, CMW, and SBW

Sorted by Sulfate

FS ID#	LAKE	WILDERNESS AREA	lab pH	uS/cm Conduct.	MG/L Ca	Mg	Na	K	NH4	P	Cl	NO3	SO4	UEQ/L ANC	MG/L SiO2
MS162	UPPER TWIN	OUTSIDE AP	7.447	63.852	10.090	1.390	0.840	0.750	0.021	0.000	0.111	0.000	9.748	471.300	7.315
MS189	CARPP LAKE	ANACONDA-P1	7.089	41.433	4.677	0.680	1.394	0.334	0.041	0.000	0.180	0.000	7.926	197.300	8.593
MS190	LOWER CARPP LAKE	ANACONDA-P1	7.062	40.618	4.439	0.657	1.414	0.456	0.056	0.000	0.213	0.000	7.394	205.500	6.841
MS163	LAKE OF THE ISLE	OUTSIDE AP	6.668	36.414	4.720	0.690	1.320	0.832	0.017	0.000	0.146	0.015	6.151	163.400	9.256
MS191	UNNAMED LAKE T3N	ANACONDA-P1	6.876	32.780	2.794	0.447	1.449	1.036	0.100	0.000	0.356	0.120	5.693	133.600	5.698
MS262	UPPER NELSON	OUTSIDE AP	7.181	33.062	4.616	0.510	0.833	0.748	0.017	1.956	0.156	0.000	3.866	146.900	4.134
MS246	HIDDEN LAKE	ANACONDA-P1	8.258	96.917	20.209	1.337	0.471	1.554	0.028	0.000	0.190	0.000	3.358	946.500	2.101
MS188	UPPER CARPP LAKE	ANACONDA-P1	6.810	17.245	2.446	0.282	0.597	0.212	0.000	0.000	0.069	0.000	2.758	116.200	3.633
MS234	UNNAMED T3NR15WS	ANACONDA-P1	6.999	27.718	2.923	0.563	1.202	0.732	0.073	0.000	0.319	0.000	2.710	156.100	5.325
MS144	STORM LAKE	OUTSIDE AP	7.927	95.161	19.310	1.540	0.640	0.658	0.186	0.000	0.123	0.000	2.536	1067.000	4.403
MS152	PAGE LAKE	ANACONDA-P1	8.414	96.892	19.310	2.185	0.448	1.052	0.029	0.000	0.202	0.000	2.536	1143.500	1.888
MS224	EDITH LAKE	ANACONDA-P1	8.146	108.152	21.546	1.609	0.750	1.893	0.028	0.000	0.229	0.000	2.465	1249.000	5.106
MS217	LITTLE RAINBOW LAK	ANACONDA-P1	7.468	33.856	5.154	0.363	0.361	0.315	0.000	0.000	0.134	0.000	2.313	264.900	1.110
MS151	UPPER SEYMOUR LAK	ANACONDA-PI	7.942	58.698	10.297	0.611	0.578	0.682	0.014	0.000	0.080	0.000	2.242	634.400	4.461
MS205	MINOR LAKE	CABINET MTS	7.649	54.024	6.810	1.288	0.568	0.452	0.035	0.000	0.187	0.000	2.028	519.500	2.823
MS153	FLOWER LAKE	ANACONDA-P1	7.690	55.045	7.811	1.579	0.716	1.172	0.047	0.000	0.496	0.538	1.930	553.800	3.326
MS238	HOLLOWAY LAKE	SELWAY-BITTE	6.481	7.578	0.863	0.156	0.363	0.292	0.007	0.000	0.104	0.000	1.782	24.600	2.107
MS244	RIPPLE LAKE	ANACONDA-PI	7.768	71.204	12.453	1.560	0.756	0.758	0.028	0.000	0.319	0.000	1.756	686.000	6.187
MS146	JOHNSON LAKE	ANACONDA-P1	8.234	140.319	29.270	2.842	0.498	1.722	0.098	0.000	0.100	0.000	1.673	1748.100	3.548
MS227	LAMARCHE LAKE	ANACONDA-P1	6.868	14.032	1.690	0.607	0.357	0.544	0.021	0.000	0.148	0.021	1.594	109.400	3.946
MS231	UPPER VIMY LAKE	CABINET MTS	6.929	39.140	4.011	0.461	2.573	1.022	0.102	0.000	2.985	0.000	1.569	181.200	1.503
MS147	MARTIN LAKE	ANACONDA-P1	8.160	109.389	22.560	1.936	0.379	1.471	0.062	0.000	0.146	0.000	1.453	1318.700	2.494
MS237	MILLS LAKE	SELWAY-BITTE	6.455	8.423	0.719	0.119	0.680	0.461	0.017	0.000	0.445	0.000	1.387	28.600	2.579
MS236	CARLTON LAKE	SELWAY-BITTE	6.434	6.567	0.290	0.119	0.685	0.215	0.017	0.000	0.182	0.000	1.349	20.500	3.567
MS182	GRANITE LAKE	CABINET MTS	7.399	39.900	4.706	1.855	0.178	0.151	0.022	0.000	0.072	0.191	1.333	404.600	1.289
MS210	BUCK LAKE	ANACONDA-P1	5.893	7.924	0.314	0.162	0.554	0.546	0.073	0.000	0.250	0.000	1.269	12.400	0.355
MS145	RAINBOW LAKE	ANACONDA-P1	7.821	58.870	11.450	0.702	0.448	1.041	0.080	0.000	0.100	0.000	1.232	697.300	3.046
MS235	LITTLE CARLTON LA	SELWAY-BITTE	6.373	8.990	0.440	0.119	1.205	0.431	0.032	0.000	0.692	0.000	1.222	30.000	4.152
MS223	HICKS LAKE	ANACONDA-P1	7.060	26.330	3.345	0.425	0.801	0.176	0.000	0.000	0.212	0.000	1.133	214.400	3.693
MS233	TAMARACK LAKE	ANACONDA-P1	6.914	16.918	2.644	0.363	0.430	0.685	0.000	0.000	0.241	0.000	1.120	139.000	1.985
MS175	UPPER FOURMILE BA	OUTSIDE AP	7.051	15.545	2.171	0.298	0.437	0.364	0.018	0.000	0.133	0.000	1.119	145.100	2.297
MS228	LOST LAKE #1	ANACONDA-P1	6.937	14.145	2.504	0.177	0.351	0.314	0.027	0.000	0.204	0.043	1.082	125.300	1.319
MS229	LOST LAKE #2	ANACONDA-P1	7.015	26.291	2.851	0.159	1.152	1.780	0.096	0.000	1.348	0.110	1.069	150.000	0.670
MS263	WARREN LAKE	ANACONDA-P1	7.097	14.482	2.582	0.287	0.566	0.246	0.012	0.000	0.161	0.000	1.033	124.000	2.748
MS192	UNNAMED T3NR15WS	ANACONDA-P1	7.737	44.487	7.198	0.192	0.289	0.334	0.061	0.000	0.254	0.529	0.961	420.300	1.232
MS215	LOWER SKY LAKE	CABINET MTS	7.535	30.153	3.999	0.914	0.508	0.477	0.000	0.000	0.163	0.000	0.960	257.200	3.407
MS235	UPPER MIDDLE FORK	SELWAY-BITTE	6.518	6.972	0.855	0.109	0.342	0.183	0.016	0.000	0.165	0.000	0.949	29.600	2.326
MS247	SAWED CABIN LAKE	ANACONDA-P1	8.055	78.387	14.663	1.133	0.471	1.080	0.028	0.000	0.241	0.000	0.942	771.500	3.833
MS193	CRYSTAL LAKE	SELWAY-BITTE	7.031	17.846	2.326	0.132	0.804	0.456	0.041	0.000	0.287	0.000	0.929	160.100	3.666
MS230	DOUBLE LAKE	CABINET MTS	6.967	10.840	3.202	0.470	0.472	0.248	0.027	0.000	0.081	0.000	0.916	144.800	1.386
MS199	BAREE LAKE	CABINET MTS	6.686	8.337	0.695	0.192	0.546	0.120	0.036	0.000	0.126	0.000	0.886	51.400	3.090
MS161	IVANHOE LAKE	ANACONDA-P1	6.621	12.536	1.672	0.323	0.234	0.387	0.032	0.000	0.151	0.272	0.833	112.500	3.382
MS214	LION LAKE	ANACONDA-P1	7.159	21.095	2.202	0.350	2.320	0.801	0.000	0.000	0.392	0.000	0.812	185.200	8.044
MS264	UPPER TENMILE	OUTSIDE AP	7.041	11.891	1.932	0.116	0.859	0.261	0.012	0.000	0.323	0.000	0.727	91.400	2.609
MS233	NORTH KOOTENAI LA	SELWAY-BITTE	6.352	5.131	0.442	0.068	0.362	0.127	0.000	0.000	0.098	0.000	0.713	18.300	2.382
MS249	ORBOMNOS LAKE	ANACONDA-PI	8.038	88.589	17.243	1.385	0.393	0.809	0.028	0.000	0.241	0.000	0.663	899.000	1.929
MS207	UPPER CEDAR LAKE	CABINET MTS	6.969	16.805	2.174	1.215	0.269	0.222	0.039	0.000	0.183	0.000	0.657	162.000	2.141
MS195	BOULDER LAKE	SELWAY-BITTE	6.622	11.666	1.225	0.079	0.723	0.609	0.041	0.000	0.688	0.000	0.610	77.600	2.464
MS216	UPPER SKY LAKE	CABINET MTS	7.959	59.248	8.653	2.093	0.245	0.871	0.046	0.000	0.170	0.000	0.601	626.800	4.362
MS165	SIAH LAKE	SELWAY-BITTE	7.148	26.010	3.114	0.601	0.352	0.303	0.013	0.000	0.079	0.000	0.549	237.900	4.593
MS211	HOPE LAKE	ANACONDA-P1	7.011	15.436	1.336	0.275	1.834	0.616	0.000	0.000	0.566	0.000	0.546	120.100	6.464
MS170	UNNAMED LAKE	ANACONDA-P1	7.030	13.351	1.715	0.448	0.293	0.407	0.022	0.000	0.134	0.000	0.530	137.000	2.816
MS183	NELSON LAKE	SELWAY-BITTE	6.665	9.392	0.931	0.132	0.683	0.242	0.036	0.000	0.143	0.000	0.482	81.800	5.384
MS150	UNNAMED LAKE	ANACONDA-P1	6.815	6.341	0.946	0.139	0.303	0.300	0.040	0.000	0.130	0.616	0.479	46.200	2.440
MS171	PHYLLIS LAKE	ANACONDA-P1	7.378	47.735	4.264	1.476	1.021	1.617	0.119	0.000	1.562	0.036	0.468	445.900	2.264
MS221	BIG CREEK LAKE	SELWAY-BITTE	6.384	6.927	0.788	0.087	0.369	0.338	0.060	0.000	0.253	0.000	0.455	40.500	2.332
MS206	LEIGH LAKE	CABINET MTS	6.872	9.496	1.303	0.403	0.209	0.104	0.041	0.000	0.155	0.000	0.426	85.200	1.220
MS174	WHITESAND LAKE	SELWAY-BITTE	6.653	8.880	1.414	0.110	0.468	0.132	0.011	0.000	0.065	0.017	0.424	86.900	3.294
MS172	UNNAMED LAKE	ANACONDA-P1	7.142	19.558	2.540	0.732	0.426	0.276	0.033	0.000	0.127	0.017	0.387	215.800	2.437
MS148	BIG CREEK LAKE	SELWAY-BITTE	6.513	4.603	0.583	0.139	0.311	0.085	0.025	0.000	0.054	0.043	0.387	28.200	2.060
MS220	CANYON LAKE	SELWAY-BITTE	6.384	9.074	0.865	0.074	0.747	0.546	0.299	0.000	0.603	0.000	0.383	46.700	2.247
MS173	LITTLE JOHNSON LAK	ANACONDA-PI	8.848	98.667	17.040	3.981	0.571	0.994	0.033	0.000	0.588	0.027	0.381	1187.100	0.633
MS260	ENGLE LAKE	CABINET MTS	6.558	6.244	0.748	0.125	0.422	0.189	0.000	0.000	0.273	0.026	0.380	35.700	3.611
MS198	UPPER BRAMLET	CABINET MTS	6.411	4.897	0.397	0.072	0.340	0.105	0.022	0.000	0.116	0.000	0.376	26.900	2.698
MS212	MYSTIC LAKE	ANACONDA-P1	7.057	12.824	1.390	0.212	1.487	0.199	0.000	0.000	0.106	0.000	0.376	115.600	5.856
MS194	UNKNOWN CANYON L	SELWAY-BITTE	6.621	10.577	1.110	0.124	0.642	0.441	0.041	0.000	0.533	0.000	0.376	76.400	2.546
MS208	SURPRISE LAKE	ANACONDA-P1	7.283	27.642	4.401	0.137	0.801	0.153	0.080	0.000	0.136	0.000	0.355	236.000	3.970
MS180	UPPER GEIGER	CABINET MTS	6.473	6.551	0.592	0.087	0.385	0.120	0.022	0.000	0.143	0.000	0.344	51.300	2.890
MS254	SOUTH KOOTENAI LA	SELWAY-BITTE	6.415	5.237	0.547	0.078	0.322	0.089	0.000	0.000	0.123	0.000	0.324	22.400	1.922
MS209	VIOLET LAKE	ANACONDA-P1	7.109	26.992	3.600	0.237	1.356	0.176	0.087	0.000	0.109	0.000	0.323	226.100	2.693
MS242	FRED BURR LAKE	SELWAY-BITTE	6.590	7.932	0.801	0.083	0.719	0.400	0.042	0.000	0.617	0.000	0.307	38.800	1.545
MS169	BILL'S LAKE	SELWAY-BITTE	6.643	4.897	0.498	0.044	0.319	0.060	0.018	0.000	0.051	0.036	0.306	35.500	2.742
MS168	EMERALD LAKE	SELWAY-BITTE	6.653	4.990	0.601	0.044	0.334	0.072	0.007	0.000	0.064	0.036	0.306	34.900	2.387
MS197	LOWER BRAMLET	CABINET MTS	6.349	4.612	0.252	0.072	0.370	0.090	0.027	0.000	0.116	0.000	0.302	24.000	3.149
MS243	LITTLE GRIZZLY LAK	SELWAY-BITTE	6.602	5.028	0.538	0.101	0.329	0.276	0.007	0.000	0.139	0.000	0.294	28.300	2.182
MS200	UPPER DEAD ELK LA	SELWAY-BITTE	6.340	5.609	0.616	0.079	0.397	0.173	0.029	0.000	0.156	0.000	0.291	34.200	2.109
MS201	LOWER DEAD ELK LA	SELWAY-BITTE	6.426	5.567	0.712	0.098	0.349	0.173	0.035	0.000	0.089	0.000	0.291	39.300	2.123
MS213	CRYSTAL LAKE	ANACONDA-P1	6.963	15.404	1.470	0.275	1.934	0.477	0.000	0.000	0.234	0.000	0.291	127.500	4.565
MS258	ROCK LAKE	CABINET MTS	6.846	7.653	1.118	0.322	0.320	0.146	0.000	0.000	0.211	0.000	0.283	59.500	1.211
MS219	WIND 7111 LAKE	SELWAY-BITTE	6.458	5.883	0.560	0.074	0.515	0.130	0.066	0.000	0.106	0.000	0.263	44.000	3.601
MS225	FISH LAKE	SELWAY-BITTE	6.591	5.372	0.664	0.104	0.460	0.116	0.027	0.000	0.084	0.000	0.262	40.200	2.054
MS257	MILEPOST LAKE	SELWAY-BITTE	6.574	5.105	0.496	0.116	0.320	0.289	0.003	0.000	0.081	0.000	0.255	30.100	2.608
MS256	BIG GRIZZLY LAKE	SELWAY-BITTE	6.570	5.869	0.496	0.099	0.376	0.361	0.003	0.000	0.194	0.000	0.255	33.400	2.484
MS204	LOTTIE #2	SELWAY-BITTE	6.514	6.526	0.760	0.089	0.745	0.139	0.000	0.000	0.134	0.000	0.253	50.900	3.480
MS156	SOUTH COLT LAKE	SELWAY-BITTE	6.644	5.122	0.505	0.057	0.490	0.127	0.028	0.000	2.120	0.000	0.247	40.900	3.453
MS155	NORTH COLT LAKE	SELWAY-BITTE	6.713	5.809	0.677	0.049	0.574	0.153	0.017	0.000	0.105	0.000	0.247	51.900	3.414
MS159	LOWER LIBBY LAKE	CABINET MTS	6.375	3.040	0.248	0.061	0.173	0.059	0.010	0.000	0.041	0.000	0.247	17.000	1.483
MS248	UNNAMED T2NR15WS	ANACONDA-P1	7.555	37.788	6.307	0.530	0.350	0.758	0.028	0.000	0.394	0.000	0.243	318.500	0.118
MS149	PEARL LAKE	SELWAY-BITTE	6.452	3.734	0.383	0.043	0.238	0.061	0.014	0.000	0.044	0.000	0.240	23.800	1.414
MS186	MIDDLE LAKE	SELWAY-BITTE	6.663	10.465	0.975	0.087	0.723	0.456	0.041	0.000	0.415	0.138	0.238	87.300	3.037
MS167	BLODGETT LAKE	SELWAY-BITTE	6.015	3.310	0.183	0.026	0.192	0.051	0.044	0.000	0.113	0.000	0.238	17.700	1.656
MS245	KELLY LAKE	ANACONDA-PI	8.788	74.744	13.080	1.774	0.647	0.775	0.039	0.000	0.335	0.000	0.230	760.200	4.364
MS157	UPPER LIBBY LAKE	CABINET MTS	5.983	1.954	0.091	0.012	0.142	0.059	0.028	0.000	0.076	0.000	0.219	6.100	0.948
MS241	LOCKWOOD LAKE	SELWAY-BITTE	6.528	6.402	0.698	0.083	0.488	0.261	0.052	0.000	0.355	0.000	0.218	38.100	2.402
MS185	GEM LAKE	SELWAY-BITTE	6.706	8.733	1.020	0.079	0.496	0.227	0.032	0.000	0.149	0.191	0.206	80.000	2.895
MS218	WIND 6790 LAKE	SELWAY-BITTE	6.509	7.388	0.814	0.087	0.677	0.176	0.000	0.000	0.209	0.000	0.199	57.300	2.276
MS178	KETTLE LAKE	SELWAY-BITTE	6.321	4.938	0.473	0.049	0.209	0.120	0.000	0.000	0.133	0.156	0.185	35.100	1.172
MS239	SHASTA LAKE	SELWAY-BITTE	6.527	4.392	0.479	0.083	0.420	0.060	0.007	0.000	0.108	0.000	0.154	24.000	3.659
MS202	MUD LAKE	SELWAY-BITTE	6.372	5.536	0.616	0.089	0.629	0.104	0.000	0.000	0.106	0.000	0.153	38.600	3.187
MS231	BUCK LAKE	SELWAY-BITTE	6.810	9.628	1.098	0.199	1.064	0.165	0.000	0.000	0.112	0.000	0.129	83.500	2.784
MS203	LOTTIE #1	SELWAY-BITTE	6.504	5.701	0.712	0.079	0.617	0.104	0.023	0.000	0.062	0.000	0.121	45.200	2.376
MS196	EAGLE MTN. LAKE	SELWAY-BITTE	6.712	4.734	0.397	0.049	0.330	0.090	0.022	0.000	0.086	0.000	0.121	39.000	3.227
MS240	HEINRICH LAKE	SELWAY-BITTE	6.500	6.725	0.617	0.055	0.714	0.369	0.017	0.000	0.707	0.000	0.078	28.300	1.362
MS259	MORAN BASIN	CABINET MTS	7.040	21.322	3.317	1.161	0.315	0.289	0.044	0.000	0.190	0.000	0.000	216.500	0.418
MS176	MAPLE LAKE	SELWAY-BITTE	6.523	5.103	0.252	0.042	0.652	0.105	0.197	0.000	0.125	0.886	0.000	43.300	4.135

Appendix 6. 1992 Anaconda Pintlar Wilderness Lakes Total Recoverable Metals in Water

	Concentrations in ug/L							
Lake	Be	Mn	Fe	Cu	Zn	As	Cd	Pb
3N14WNW512	<mdl	3.47	128.6	<mdl	12.79	<mdl	<mdl	1.07
4 Mile Basin	<mdl	12.64	35.72	<mdl	35.58	<mdl	<mdl	<mdl
Apw-Johnson	<mdl	1.82	107.34	<mdl	<mdl	<mdl	<mdl	<mdl
Buck	<mdl	4.61	20.47	<mdl	12.35	1.47	2.82	<mdl
Carpp	<mdl	1.03	19.77	<mdl	136.3	<mdl	<mdl	<mdl
Crystal	<mdl	5.24	85.92	<mdl	6.85	<mdl	<mdl	<mdl
Edith	<mdl	3.27	57.9	<mdl	22.86	<mdl	<mdl	<mdl
Flower	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Hidden	<mdl	5.79	74.48	<mdl	31.23	<mdl	<mdl	<mdl
Hicks	<mdl	3.7	19	<mdl	<mdl	<mdl	<mdl	<mdl
Hope	<mdl	4.04	61.5	<mdl	35.35	<mdl	5.27	1.23
Ivanhoe	<mdl	1.33	14.45	<mdl	7.19	<mdl	<mdl	<mdl
Kelly	<mdl	5.97	146.97	<mdl	52.7	<mdl	<mdl	1.2
Lake of the Isle	<mdl	1.69	36.85	<mdl	3.6	1.04	<mdl	4.13
LaMarche	<mdl	1.64	58.89	<mdl	29.33	<mdl	<mdl	<mdl
Little Rainbow	<mdl	3.5	66.1	2.7	<mdl	0.8	<mdl	<mdl
Lion	<mdl	2.38	38.43	<mdl	<mdl	<mdl	<mdl	<mdl
Little Johnson Lk	<mdl	1.34	44.48	<mdl	5.73	<mdl	<mdl	<mdl
Lost #1	<mdl	<mdl	28.73	<mdl	15.45	<mdl	<mdl	<mdl
Lost #2	<mdl	<mdl	21.23	<mdl	5.36	<mdl	<mdl	<mdl
Lower Carp	<mdl	1.73	34.96	<mdl	14.46	<mdl	<mdl	<mdl
Martin	<mdl	2.28	82.77	<mdl	<mdl	<mdl	<mdl	<mdl
Mystic	<mdl	1.43	25.95	8.06	10.6	<mdl	<mdl	<mdl
Nelson	<mdl	1.69	41.94	4.79	12.31	<mdl	<mdl	<mdl
NES22 T3N R15W	<mdl	2.18	31.25	2.63	9.24	1.27	<mdl	<mdl
Oreomnos	<mdl	3.51	63.05	<mdl	15.04	<mdl	<mdl	<mdl
Page	<mdl	1.49	47.64	<mdl	6.03	<mdl	<mdl	<mdl
Phylus	<mdl	1.18	25.72	<mdl	7.61	<mdl	<mdl	<mdl
Rainbow	<mdl	4.16	69.92	<mdl	8.37	1.09	<mdl	<mdl
Ripple	<mdl	3.54	69.9	<mdl	49.37	<mdl	<mdl	<mdl
Sawed Cabin	<mdl	1.89	76.04	<mdl	31.06	<mdl	<mdl	<mdl
Storm	<mdl	12.47	88.55	<mdl	17.46	<mdl	<mdl	<mdl
Surprise	<mdl	<mdl	12.66	<mdl	7.75	<mdl	<mdl	<mdl
Tamarack	<mdl	1.3	22.8	<mdl	5.3	<mdl	<mdl	<mdl
T2NR15W SWS6	<mdl	<mdl	18.8	<mdl	3.85	<mdl	<mdl	<mdl
T3NR15W S16	<mdl	1.3	22.8	<mdl	5.3	<mdl	<mdl	<mdl
T3NR15W SWS22	<mdl	<mdl	71.8	<mdl	25.48	<mdl	<mdl	<mdl
T3NR16W SES35	<mdl	1.42	27.44	<mdl	4.88	<mdl	<mdl	<mdl
Tenmile	<mdl	2.7	26.37	5.53	11.85	1.35	<mdl	1.54
Unnamed T2N	<mdl	1.01	27.28	<mdl	4.88	<mdl	6.57	<mdl
Upper Carp	<mdl	1.85	16.67	<mdl	10.44	<mdl	<mdl	<mdl
Upper Seymour	<mdl	1.97	32.06	<mdl	<mdl	<mdl	<mdl	<mdl
Upper Twin	<mdl	1.91	72.18	<mdl	20.63	<mdl	<mdl	<mdl
Violet	<mdl	3.41	43.34	<mdl	14.54	<mdl	<mdl	<mdl
Warren	<mdl	1.22	22.69	<mdl	3.72	<mdl	<mdl	<mdl

Appendix 7. Anaconda Pintlar Wilderness 1992 Lake Sediment Core Samples

HNO3/H2O2 Digestion, Corrected to Dry Weight mg/kg (ppm)

Left to Right in order of Distance from Smelter

Analyte	Symbol	ERA Lot 213 Soil Sample	Lake of the Isle	Upper Twin	Storm	Page	Upper Carpp	Rainbow	Rainbow Dup	Johnson	Mystic	Surprise
Aluminum	Al	>1173	>487.9	>180.1	>701.3	>526.2	>416.3	>1061	>1061	>557.1	>226.5	<mdl
Antimony	Sb	23.24	0.02	0.01	0.04	0.05	0.02	0.27	0.28	0.02	0.01	0.01
Arsenic	As	137.6	1.21	0.24	1.22	0.94	0.47	14.7	16.77	0.42	0.07	0.04
Barium	Ba	810.6	41.28	5.56	14.46	97.22	16.23	133.2	128.6	37.35	8.14	0.16
Beryllium	Be	121.7	0.82	0.05	0.11	0.22	0.1	0.59	0.41	0.11	0.09	0.04
Bismuth	Bi	0.22	0.11	0.03	0.03	0.11	0.31	0.25	0.42	0.05	0.01	<mdl
Boron	B	1.8	0.78	0.05	0.44	0.33	0.18	0.29	0.18	0.29	0.12	0.18
Bromine	Br	22.7	4.84	1.44	17.81	3.1	1.86	0.7	5.43	5.4	1.46	1.23
Cadmium	Cd	152.1	0.11	0.03	0.09	0.05	0.53	0.18	0.1	0.03	0.012	0.01
Calcium	Ca	6790	251.6	139.4	2078	1099	228.2	6776	5912	1648	68.18	105.4
Cerium	Ca	36.22	3.15	0.53	3.24	3.89	2.05	19.17	21.45	3.25	0.51	0.49
Cesium	Cs	1.85	0.6	0.15	0.68	1.25	0.71	4.68	4.97	1.36	0.04	0.49
Chlorine	Cl	1173	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Chromium	Cr	135.4	1.75	0.86	2.66	2.19	2.05	9.21	8.87	4.09	0.28	0.27
Cobalt	Co	204.5	1.59	0.65	1.16	1.2	0.89	4.18	4.67	1.92	0.11	0.12
Copper	Cu	145.7	8.78	1.57	4.15	3.82	8.86	7.08	9.1	3.17	0.31	0.39
Dysprosium	Dy	1.85	0.36	0.05	0.28	0.51	0.18	1.05	1	0.56	0.07	0.09
Erbium	Er	0.78	0.18	0.03	0.17	0.31	0.07	0.54	0.54	0.32	0.04	0.04
Europium	Eu	0.56	0.18	0.02	0.05	0.13	0.05	0.27	0.26	0.1	0.02	0.04
Gadolinium	Gd	2.81	0.53	0.07	0.29	0.54	0.21	1.42	1.25	0.55	0.09	0.12
Gallium	Ga	3.6	0.62	0.15	1.02	2.83	0.49	4.07	3.89	1.42	0.09	0.15
Germanium	Ge	0.05	0.02	<mdl	0.03	0.05	0.09	0.12	0.11	0.09	35	<mdl
Gold	Au	0.01	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Hafnium	Hf	0.31	0.05	0.01	0.03	0.12	0.01	0.16	0.12	0.03	<mdl	<mdl
Holmium	Ho	0.33	0.09	0.01	0.05	0.11	0.03	0.21	0.21	0.11	0.01	0.02
Indium	In	0.03	0.01	<mdl	<mdl	<mdl	0.01	0.01	0.01	0.01	<mdl	<mdl
Iodine	I	0.09	0.14	0.02	0.28	0.11	0.04	0.01	0.02	0.17	0.04	0.04
Iridium	Ir	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Iron	Fe	9805	1009	591.1	1176	1476	667.7	7746	7091	2497	150.5	124.8
Krypton	Kr	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Lanthanum	La	16.19	2.46	0.32	1.58	2.79	1.19	10.66	11.27	1.63	0.3	0.84
Lead	Pb	136.4	1.96	0.31	1.4	1.72	16.9	12.21	16.66	1.78	0.25	0.21
Lutetium	Lu	0.11	0.02	<mdl	0.03	0.05	0.01	0.07	0.078	0.05	0.01	0.01
Magnesium	Mg	3500	264.9	161.4	1535	1236	707.5	6060	6060	3737	33.5	46.17
Manganese	Mn	390.7	9.61	6.17	32.65	23.05	9.46	>436.2	>436.2	47.17	5.52	2.19
Mercury	Hg	53.08	<mdl	0.02	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Molybdenum	Mo	180.2	1.14	0.42	0.35	1.85	0.13	0.17	0.12	0.1	0.03	0.05
Neodymium	Nd	17.66	2.78	0.32	1.5	2.58	1.13	8.54	9.09	1.73	0.36	0.84
Nickle	Ni	172.9	4.53	0.78	1.46	1.46	1.74	5.56	5.74	2.23	0.19	0.17
Niobium	Nb	1.24	0.21	0.05	0.41	0.54	0.17	0.23	0.53	0.4	0.04	0.04
Osmium	Os	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Palladium	Pd	<mdl	0.01	<mdl	0.01	0.02	<mdl	0.02	0.02	0.01	<mdl	<mdl
Phosphorus	P	<mdl	3.27	1.42	9.12	3.46	2.89	<mdl	<mdl	4.65	1.74	0.74
Platinum	Pt	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Potassium	K	>152.6	37.82	14.72	33.36	>66.57	34.03	>136.3	>136.3	>72.59	4.63	5.63
Praseodymium	Pr	4.51	0.67	0.08	0.36	0.65	0.29	2.2	2.24	0.41	0.09	0.18
Rhenium	Re	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Rhodium	Rh	0.01	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Rubdium	Rb	19.28	1.53	0.54	1.46	2.84	1.58	28.27	28.09	4.36	0.21	0.18
Ruthenium	Ru	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Samarium	Sm	3.46	0.55	0.05	0.29	0.51	0.23	1.61	1.43	0.42	0.05	0.13
Scandium	Sc	0.56	0.09	0.02	0.05	0.1	0.04	0.36	0.36	0.17	0.01	0.02
Selenium	Se	77.22	<mdl	0.02	0.11	0.11	0.04	0.05	<mdl	0.1	0.07	<mdl
Silicon	Si	127.9	63.94	9.76	53.75	54.46	27.76	63.44	110.5	75.59	11.61	19.57
Silver	Ag	18.36	0.04	0.01	0.02	0.04	0.1	0.96	1.23	0.02	0.01	0.01
Sodium	Na	219.3	7.36	1.88	20.28	32.53	8.77	96.41	92.91	17.08	2.04	2.65
Strontium	Sr	62.04	5.2	0.92	3.21	8.34	2.42	5.34	4.71	1.77	2.87	1.03
Sulfur	S	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Tantalum	Ta	<mdl	0.01	<mdl	0.03	0.02	0.01	<mdl	<mdl	0.01	<mdl	<mdl
Tellurium	Te	0.05	<mdl	<mdl	<mdl	<mdl	0.01	0.02	0.04	<mdl	<mdl	<mdl
Terbium	Tb	0.37	0.07	0.01	0.04	0.05	0.03	0.19	0.18	0.05	0.01	0.02
Thallium	Tl	81.96	0.02	0.01	0.03	0.04	0.03	0.21	0.2	0.04	<mdl	<mdl
Thorium	Th	2.8	0.11	0.03	0.22	0.21	0.07	3.63	3	0.28	0.01	0.02
Thulium	Tm	0.11	0.03	<mdl	0.03	0.05	0.01	0.05	0.05	0.05	0.01	0.01
Tin	Sn	1.89	0.96	0.45	1.55	1.36	0.85	2.34	2.18	1.21	0.31	0.97
Titanium	Ti	323.6	95.07	37.09	142.8	156.2	67.37	549.2	426.9	202	14.66	15.24
Tungsten	W	0.28	0.1	0.21	0.21	0.49	0.37	0.32	1.02	0.05	0.01	0.01
Uradium	U	0.37	0.07	0.05	0.33	1.12	0.07	0.18	0.15	0.07	0.04	0.23
Vanadium	V	145.5	2.18	1.84	2.96	3.63	1.33	10.96	10.55	4.36	0.49	0.42
Xenon	Xe	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Ytterbium	Yb	0.66	0.17	0.02	0.18	0.29	0.07	0.5	0.5	0.31	0.03	0.04
Yttrium	Y	7.13	1.77	0.27	1.49	3.18	0.72	4.65	4.79	2.96	0.29	0.45
Zinc	Zn	464.8	10.66	3.34	7.46	6.95	46.12	38.34	61.61	10.96	1.02	1.39
Zirconium	Zr	8.72	1.84	0.23	1.18	4.37	0.41	3.42	3.24	1.24	0.15	0.32

Appendix 8. Anaconda Pintlar Wilderness 1992 Lake Sediment Core Samples

H202 Digestion, Sonnicator, HCl/HN03 Extraction, Microwave, ICP-AE5

LAKE	DISTANCE MILES	Aluminum ppm	Cadmium ppm	Cobalt ppm	Chromium ppm	Copper ppm	Iron ppm	Manganese ppm	Nickle ppm	Lead ppm	Vanadium ppm	Tungsten ppm	Zinc ppm
LAKE OF THE ISLE	13.40	23300	0.81	7	12.5	43.10	9820	71	30.6	214.0	15.3	7.3	75.1
UPPER TWIN LAKE	14.50	16500	1.23	19	27.2	46.30	25000	257	22.6	154.0	50.5	27.9	110.9
UPPER SEYMOUR	17.80	19500	0.63	5	11.2	18.10	10400	105	8.6	182.0	17.5	15.4	30.3
RAINBOW LAKE	27.80	14600	0.62	6	11.7	11.10	15100	470	9.5	145.0	11.6	10.8	42.5
JOHNSON LAKE	30.50	24700	0.51	7	20.7	19.20	16800	234	12.5	228.0	21.5	16.5	60.2
SURPRISE LAKE	42.00	11800	0.41	3	6.9	14.90	5270	72	6.3	108.0	13.9	4.8	43.0
MYSTIC LAKE	42.40	7300	0.40	2	5.6	9.00	4910	137	5.2	73.0	10.7	0.0	28.2
UPPER CARPP	27.00	19100	7.68	8	25.6	147.80	11100	122	24.3	463.0	16.6	83.6	713.0